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THE TUNA/PORPOISE PROBLEM: DEDICATED VESSEL RESEARCH PROGRAM

Summary of the Research Results from the Fifth
Cruise of the Dedicated Vessel
11 November to 9 December 1978

V

by

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ABSTRACT

The tuna industry and the Federal Government sponsored the tuna seiner M/V Queen Mary during 1978 as a research platform for studies related to the tuna/porpoise problem. Between November 11 and December 10, 1978, the research focused on reducing porpoise mortality.

The primary objectives during the first leg of the cruise were to describe and measure various parameters of purse seining including the interaction of the net, seiner and net skiff. The primary objective of the second leg was to film movie footage of the fishing operation, and porpoise rescue gear and techniques for production of a 20 minute skipper/observer training film.

Fifteen sets were made during the cruise; three were diving research sets and 12 were porpoise sets. Two offshore spotters and nine eastern spinners were killed during three of the porpoise sets. One hundred short tons of yellowfin and skipjack tuna were loaded during the cruise.

The seine's sub-surface configuration while pursing, rolling, and backing down was observed by SCUBA divers during 10 sets. Mesh shapes and tensions were measured and photographed to a depth of 130 feet. Sub-surface photographs and observations collected during five backdowns have lead to the identification of the primary factors responsible for stern sway and canopies. Sub-surface configuration of the net while pursing and net rolling were examined with a fathometer during seven sets. Excellent bottom traces were obtained during these sets. The force required to purse the seine was measured in two ways. During five sets hydraulic pressures and winch torque were used to calculate line pull on the purse cable. During three sets the cable tension was measured with a dynamometer and pursing forces were calculated. The skiff's pulling forces were measured during one set.

Seven thousand feet of 16 mm movie film were shot. Currently a training movie is being prepared. Short animated sections are being cut into the film to enhance particular subjects that were not filmed.

Dorsal fin tags released during Cruise IV of the Dedicated Vessel were seen during three sets and one aborted chase.

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I. INTRODUCTION

Thousands of oceanic porpoise (Stenella spp. and Delphinus sp.) are incidentally killed or seriously injured each year during the course of purse seining for yellowfin tuna (Thunnus albacares) in the Eastern Tropical Pacific (ETP). During the period 1972-1977, the United States purse seine fleet reduced the kill of porpoise by 87.4 percent (from an estimated 309,000 to an estimated 27,000). However, a goal of the Marine Mammal Protection Act of 1972 is to reduce the incidental kill and the serious injury rate to insignificant levels approaching zero. Numerous fishing trips and research cruises since 1972 have contributed to the development of methods for reducing this incidental mortality by a significant amount; however, no single vessel has been designated to study and research this problem exclusively.

During all previous research cruises aboard tuna purse seiners, the research was secondary to the capture of tuna because the incentive to the seiners to carry researchers was the opportunity to capture a special allocation of tuna within an otherwise closed area. For a number of years, it has been recognized that a vessel should be dedicated for tuna/porpoise research free of fishing pressures. In 1977, the United States Tuna Foundation agreed to charter a tuna purse seiner for exclusive tuna/porpoise investigations during 1978.

The Cooperative Dedicated Vessel Research Program was a year-long government/industry research effort intended to: (1) refine and develop fishing gear and procedures to further reduce the incidental mortality or serious injury of porpoise; and (2) provide demographic and biological data needed to better assess the impacted porpoise stocks. The program was carried out under the terms of a tripartite agreement signed on 30 December, 1977, by the Marine Mammal Commission (MMC), National Marine Fisheries Service (NMFS), and United States Tuna Foundation (USTF). Pursuant to the terms of the agreement, the USTF chartered the M/V Queen Mary and made it available in January, 1978. The NMFS, USTF, MMC, and the National Science Foundation (NSF) provided research funds and support. Proposals for relevant research were accepted from all interested persons and organizations.

The NMFS and the USTF provided the research funds for Cruise V, the final cruise of the Dedicated Vessel. Mr. David Holts, NMFS, was the Cruise Leader. Other scientific personnel were: Mr. Serge Birk, NMFS; Mr. Richard N. Butler, NMFS (Leg 1); Dr. Thomas Delmer, Science Applications, Inc (Leg 1); Mr. Dale Fellbaum, NMFS (Leg 2); Mr. William Irwin, NMFS (Leg 2); Mr. Rodney McLain, a contractor to Living Marine Resources, Inc.; and Mr. Thomas Shay, NMFS.

The M/V Queen Mary departed San Diego on 11 November 1978 and returned on 9 December 1978, after a 29-day trip. Cruise V was divided into two legs of 17 days and 11 days. One day was spent in Acalpulco, Mexico, to exchange part of the scientific crew. The area of research operations was in the Eastern Tropical Pacific (ETP) within the Inter-American Tropical Tuna Commission Regulatory Area (CYRA). The cruise track is shown in Figure 1.

Cruise V was split into two legs; the focus of the research on the first leg was to identify, describe, and measure specific parameters of the purse seining operation; the focus of the second leg was to film purse seine operations, porpoise safety gear, and rescue procedures. Porpoise behavior observations were made on both legs. Ancillary objectives were also developed to take advantage of all research opportunities. This report will be divided along the lines of research just mentioned.

This report summarizes the research activities from Cruise V. It was compiled from reports received from Mr. David Holts, the Cruise Leader and from Mr. Rodney McLain and Mr. Franklin G. Alverson, LMR. The knowledge gained and the data generated from this cruise will be used by Science Applications, Inc., to build a simulation model of a purse seine net. A report will be issued after the model is completed. A movie to augment skipper workshops and observer training sessions is being produced by NMFS from the film footage taken on Cruise V.

The authors are deeply indebted to Captain Ralph Silva, Jr., and the crew of the M/V Queen Mary for their assistance, cooperation and dedication during Cruise V. The authors wish to thank Ms. Linda M. Kadubec for typing and setting up the tables for this report and to thank Mr. Kenneth S. Raymond, Mr. Roy M. Allen and Ms. Evelyn D. Portillo for providing the drawings.

II. VESSEL AND EQUIPMENT

The M/V Queen Mary, built in 1969, is 46.1 m (151 ft) long, and has a 10.4 m (34 ft) beam and a 5.2 m (17 ft) draft. She is propelled by twin Caterpillar diesel engines, 1125 horsepower each, that provide a maximum speed of 12.5 knots. She is equipped with a Caterpillar 333 bowthruster, a Marco #W1062 seine winch, and a 1.1 m (42-inch) Marco power block. Depending on fish size, the vessel can carry 520 to 550 tons[1/] of tuna in seven pairs of brine wells and one pair of stern boxes. The net is 1024 m (560 fa) long, 11 strips[2/] deep, with 348 m (190 fa) of double-depth porpoise safety panel 1¼-inch mesh) and a super apron. The net skiff, built in 1977, is 9.2 m (30 ft) long and has a beam of 5.5 m (18 ft). It weighs 15,876 kg (35,000 lb) and is powered by a 325 horsepower Caterpillar diesel engine.

The research equipment used on Cruise V included a variety of measuring and recording instruments (Appendix 1). In addition to standard SCUBA diving gear, an Ingersol-Rand air compressor with a 5,000 cubic-foot cascade air-reservoir system was aboard. A four-man inflatable boat powered by a 5-horsepower outboard engine served as the diver support boat. It was launched and retrieved from the seiner's bow with a crane.

A portable Furno fathometer, Model FG-200 Mark 3, modified so that its chart speed could be varied, was used to record subsurface net profiles. The fathometer's transducer was attached to the boat's transom so that it was vertical and constantly submerged.

[1/] Catch weights are recorded in U.S. short tons (2,000 lb or 909 kg)

[2/] The depth of a standard strip is one hundred 4¼-inch meshes.

Figure 1. Cruise track, Dedicated Vessel, Cruise V

⊘ Location of tagging sets, Cruise IV

▨ Area of tag resights on Cruise V

A series of Dillon dynamometers with a range of 0-9,000 kg (0-20,000 lb) was used to measure pursing cable tensions, net skiff towing forces, and corkline forces during backdown. Two pad-eyes were welded to the working deck directly below the pursing cables for attaching the dynamometers during the pursing tension measurements.

A Chatillon brass spring scale, modified for easy attachment to webbing, was used to measure the mesh tensions. A Leitz range finder Model 4394 was used to determine corkline distances from the seiner.

Two Cannon Scopic 16mm movie cameras (with portable power packs) were used for filming. Commercial Ectachrome 7262 was used for all the filming.

III. SUMMARY OF CRUISE STATISTICS

A. Statistics

An estimated[1/] 9,211 porpoise were pursued and 3,464 were captured in 12 porpoise sets on Cruise V. There were 85 tons of yellowfin and 15 tons of skipjack tuna captured, and 12 porpoise were killed incidentally to the research. Three sets were made specifically to conduct diving research; there were no porpoise or tuna involved in those sets. Ten of the fifteen sets were classified as gear sets and five as movie sets, although gear research and filming were conducted during all sets. A summary by set type is presented in Table 1, and the data for each set is presented in Table 2. A summary of research by set is presented in Table 3.

Table 1. Summary of Cruise V statistics

Set Type	No. Sets	Porpoise Chased	Porpoise Captured	Porpoise Killed	Tons Tuna	Kill/ Set	Kill/ Ton
Gear	7	7785	2752	12	81	1.71	.15
Filming*	5	1426	712	0	19	0	0
Diving research (waterhaul)	3	-	-	-	-	-	-
TOTAL	15	9211	3464	12	100	1.00	.12

*Filming was done during all sets on an opportunistic basis.

B. Porpoise Mortality

Four offshore spotters and eight eastern spinners were killed incidentally to research and fishing operations. Three died from individual entanglement at the apex during backdown, two died at the apex from unidentified causes, and seven died deep in the net from unidentified causes prior to or during backdown.

1/ All estimates of school size are crew estimates unless otherwise noted.

Table 2. Set log summary

Set No.	Date (1978)	Position		Duration of Chase (min)	Set Time	Porpoise Chased			Porpoise Captured			Porpoise Killed		Tons	Tuna
		Lat (N)	Long (W)			Offshore Spotters	Eastern Spinners	Total	Offshore Spotters	Eastern Spinners	Total	Offshore Spotters	Eastern Spinners	YF	SJ
1	11-14	18°51'	115°14'	-	1603	← Diving research set →									
2	11-16	17°00'	110°56'	-	1530	← Diving research set →									
3	11-18	12°08'	109°48'	16	1216	67	508	575	44	331	375	0	1	1	0
4	11-21	09°14'	107°26'	-	1621	← Diving research set →									
5	11-23	10°51'	107°38'	17	0721	372	53	425	284	41	325	0	1	8	0
6	11-23	12°05'	107°31'	59[1/]	1608	1200	300	1500	482	85	567	0	0	15	0
7	11-24	12°22'	107°41'	11	0720	-	68	68	-	68	68	-	0	0	5
8	11-24	12°58'	107°10'	25	1521	2000	2000	4000	778	389	1167	3	7	35	5
9	11-25	12°52'	106°57'	41	0810	650	-	650	250	-	250	0	-	9	3
10	11-26	15°09'	103°10'	17	1259	567	-	567	-	-	-	-	-	-	-
11	11-30	12°02'	102°54'	11	1658	500	-	500	500	-	500	0	-	6	1
12	12-01	12°23'	103°43'	23	1148	50[2/]	-	50[2/]	80	-	80	0	-	6	0
13	12-03	12°32'	106°40'	17	0751	200	-	200	-	-	-	-	-	-	-
14	12-03	12°58'	107°06'	33	1424	540	60[2/]	600[2/]	60	-	60	0	-	4	1
15	12-06	18°29'	114°02'	12	1308	76	-	76	72	-	72	0	-	1	0
TOTALS						6222	2989	9211	2550	914	3464	3	9	85	15
AVERAGE				23.5		566	498	768	233	183	346				

[1/] This chase was delayed by speedboat malfunctions. The actual chase time was about 30-40 minutes.

[2/] Observer "best" estimate.

Table 3. Research emphasis by set

Set Number	Set Type	SCUBA Diving Activities			Measurements of Net Configuration		Measurements of Pursing Rates and Forces	Filming the Training Movie
		Measurements of Mesh Shape and Tension	Observations of Backdown Canopies	General Observations and Photography	Surface Config. and Retriev. Rates	Fathometer Profiling		
1	Test[1/]			✓	✓	✓		
2	Test	✓			✓	✓		
3	Porpoise		✓		✓			
4	Test	✓		✓	✓			
5	Porpoise	✓	✓			✓		
6	Porpoise							
7	Porpoise		✓			✓		
8	Porpoise		✓	✓		✓		
9	Porpoise		✓	✓				
10	Skunk			✓				✓
11	Porpoise						✓	✓
12	Porpoise				✓		✓	✓[2/]
13	Skunk				✓		✓	✓
14	Porpoise			✓			✓	✓
15	Porpoise				✓		✓	✓
TOTAL		3	5	6	12	7	6	5

[1/] Test sets were waterhauls for diving research

[2/] Speedboats towed on the net for film documentation

C. Porpoise Tag Resights

Dorsal fin tags released during the fourth cruise were observed on four occasions (Table 4). During Set 6, one orange tetracycline tag was observed in the net. The animal appeared to be in healthy condition and was released during backdown. During Set 8, one orange, square tag was observed and photographed. This animal appeared healthy; however, the tag was loose and had migrated about an inch posteriorly. A second animal had apparently shed its tag, as evidenced by a groove almost halfway through the base of the dorsal fin. These two animals in Set 8 swam together at all times and were both photographed. Three orange tetracycline tags were observed and photographed in Set 9. Two of these were inspected and the number 0346 observed. One of the tags appeared in place, while the other had migrated back somewhat. Both surface and underwater photographs were obtained. One additional tag was observed on December 4 during an aborted chase.

Table 4. Porpoise tag resights

Date	Time	Position	Set No.	Tag Type	Condition
Nov. 23	1608 hr	12°05'N,107°31'W	6	Orange "T"	Animal and tag appeared good
Nov. 24	1512 hr	12°58'N,107°10'W	8	Orange "T"	Animal appeared good but tag had migrated about an inch toward trailing edge of dorsal fin. Photos taken.
Nov. 25	0810 hr	12°52'N,106°57'W	9	Orange "T"	#0346 animal traveled 274 km NW in 48 days. Good condition.
Nov. 25	0810 hr	12°52'N,106°57'W	9	"T"	One in place and appeared good,
Nov. 25	0810 hr	12°52'N,106°57'W	9	"T"	one loose and had migrated back somewhat. Photos taken.
Dec. 4	1330 hr	12°50'N,108°36'W	No Set	Orange ?	Tag observed during chase - no set.

IV. PURSE SEINE PARAMETERS

A. Background

The basic operation of purse seining has been described in the literature. However, many purse seine parameters directly

related to porpoise mortality are either poorly understood or are so variable that only gross assumptions of their importance can be made. The operation of setting out, closing, and retrieving the purse seine is a dynamic process from beginning to end. The interactions of the vessel, net skiff, and net cannot be completely separated from each other or from environmental conditions. However, many of the procedures can be measured independently within their normal levels of operation.

In October 1978, NMFS contracted with Science Applications, Inc. (SAI), to study the feasibility of mathematically simulating the purse-seine process. An accurate simulation model of the purse seine process would allow for the testing of a wide range of ideas for modifying gear and techniques to reduce porpoise mortality and increase fishing efficiency. Ideas appearing feasible in the model could be tested at full-scale at a considerable saving of development time and cost. To produce the most accurate simulation model possible, many of the physical parameters of the purse-seine process needed to be described and measured under normal operating circumstances. In close consultation with SAI personnel, the research during Cruise V focused on measuring those factors most critical to modeling purse-seine net dynamics.

B. Objectives

The objectives were to measure the following parameters of the purse seine operation:

1. Mesh shape, and the tension between the meshes at selected depths of the seine during specific phases of the set.

2. Surface configuration and bottom profiles of the net during the set sequence.

3. Pursing rates and the forces required to purse the net.

4. Thrust of the skiff while the net was being set and while the net was being pursed.

C. Methods

1. Mesh shapes and tensions

To identify the major stress points on the net during the seining operation, SCUBA divers measured the tension and photographed the mesh shape at the top of each strip of webbing. This was done at rings-up at the stern one-quarter net, during net roll at the mid-net zipper, and at the backdown apex. One diver measured mesh tensions with a modified spring scale as he held a plastic

grid against the web. The other diver photographed the grid and mesh shapes with a Nikonis IV underwater camera and recorded depth and time. The mesh angles were determined in the laboratory after the film was processed. The measurements were made on an 8-in-by-10-in Xerox copy of the slide. The angles, measured at the top of several meshes, were averaged.

All SCUBA diving operations followed NOAA's Diving Regulations and Safety Rules.[1/] Diving procedures (Appendix 2) varied little between dives. The dive team comprised a Dive Master (as backup diver), two divers, and a dive tender. The Dive Master remained at the surface with the dive tender in a four-man inflatable boat to oversee the diving operation and to assist primary divers, if necessary. A smaller, unmanned inflatable raft was tethered to the corkline in the dive area for additional support. While the divers were making their measurements, the Dive Master and tender recorded bottom profiles of the net with the fathometer to verify depths recorded by the divers.

2. Surface configurations and bottom profiles of the net

To map the surface configuration of the net, twelve 1.9 m (50-inch) circumference pneumatic buoys were placed around the net at 50-fathom (300 ft) intervals. The buoys were numbered sequentially from the stern; thus, buoy #1 was the first buoy to arrive at the vessel when net rolling started. The rate of retrieval of the net was determined by recording the time each of the numbered buoys entered the power block. Changes in the corkline configuration (e.g., rate of corkline advance and subsequent formation of stern and bow bends) were measured by recording the distances of the 12 buoys from the seiner with a Leitz rangefinder. The measurements were made two or three times during pursing and again during net rollup. All measurements were taken from atop the pilot house.

The bottom profiles of the seine were mapped by running transects with the fathometer-equipped diver-support boat. The depth measurements were recorded in feet and then converted to meters. The fathometer had been modified so the chart speed could be varied; however, the fastest chart speed of 5 cm/min was always used. To relate the fathometer tracings to the profile of the net, it was necessary to know the speed that each transect was run. The boat's speed was calculated by throwing a wad of paper ahead of the bow and measuring the time required to travel two meters, measured on the side of the boat, with a stopwatch. Boat speed was measured for every transect, and the throttle was held constant throughout the transect.

[1/] NOAA Diving Manual, 1974: U.S. Government Printing Office

General observations of net configuration, profile of the backdown channel, porpoise behavior and mortality were recorded by the SCUBA divers whenever possible. The observations were recorded on slates and with the "wet tape" tape recorder. The detailed observations from each diving operation were then fully documented during a debriefing session immediately following the set.

3. Pursing rates and forces

The rate of pursing was measured by recording the time required for a marker on the purse cable to travel the 4.4 meters between the purse davit and the winch (Figure 2) at selected times during pursing.

The pursing forces were measured in two ways. The first and most accurate method was a direct conversion from a measurement taken with a dynamometer. The dynamometer (Dilon, 4,540 kg; 22.7 kg divisions) was attached to a snatch block riding on one of the purse cables (Figure 2). At the start of pursing, the snatch block was placed on one of the cables and tightened until the cable was depressed approximately 10 degrees. Photographs were taken to measure the precise angle of depression. Maximum and average working tensions were recorded at selected times throughout the pursing operation. Average working tensions were determined subjectively by the observer after watching the dynamometer for 1 minute. The true force (line pull) required at the winch to purse the net was calculated by the formula:

$$F = \frac{T - \text{wt. of block},}{\sin \phi} \qquad (1)$$

where F = force (line pull) at the winch,

T = tension on the purse cable,

$\sin \phi$ = sine of the angle formed by depressing the purse cable.

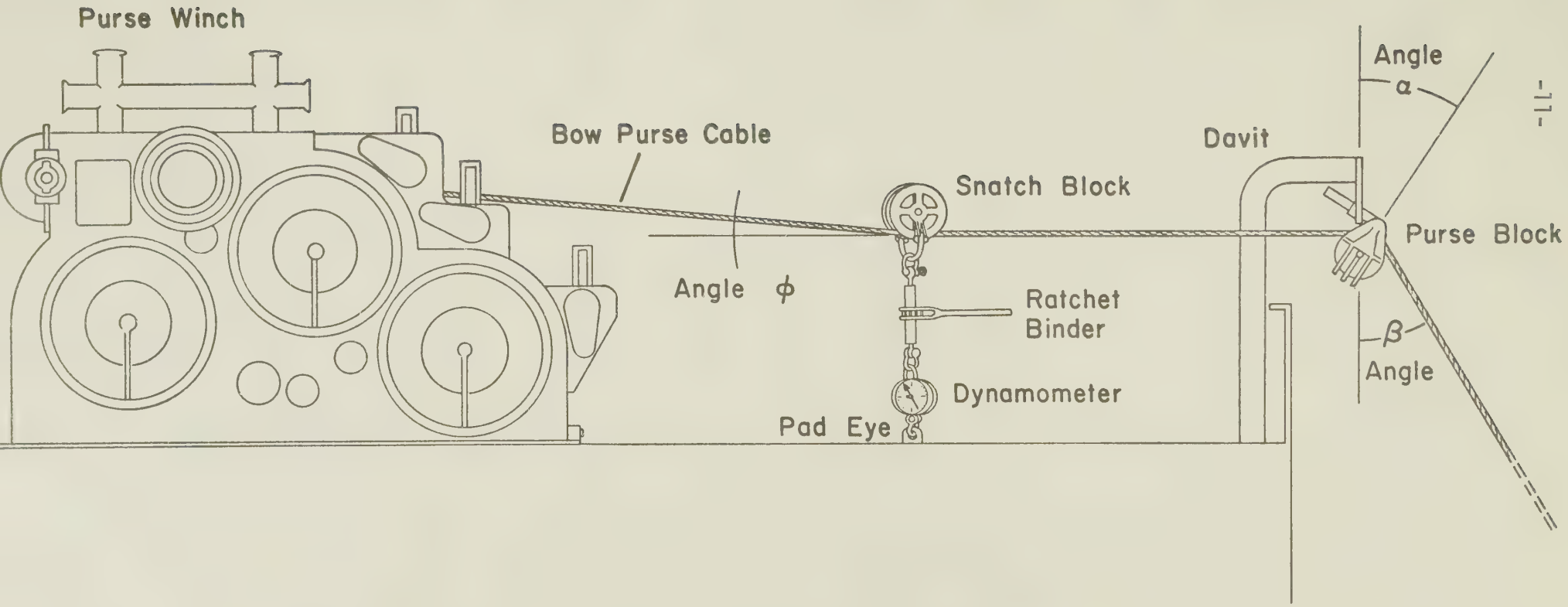

Figure 2. Measurements of cable tension with a dynamometer

The purse cable tension as it entered the water (F_w) was then calculated by the formula:

$$F_w = F \cdot \frac{\text{Sin } (90° - \alpha - \emptyset)}{\text{Sin } (\alpha + \beta)}, \qquad (2)$$

where F = line pull at the winch,

α = angle of davit block,

β = angle of cable entering the water,

$\emptyset$ = angle of cable depression at the dynamometer.

The angles α and β were not measured at the time of pursing. They were estimated from subsequent water hauls in local waters and from model tests. While these estimates are not exact, it is believed they are reasonably close to the true values.

The second method of determining pursing forces involved calculating the winch torque and efficiency of the hydraulic system. This method was considered less accurate than the first. Hydraulic pressures were used in equation (3) to calculate line pull.

$$\text{Line pull} = \frac{\text{Pressure - tare (efficiency)}}{\text{Drum torque}}, \qquad (3)$$

and $$\text{Line pull} = \frac{P_s - 400(118.9)}{(47.2-m)+(35.8-b)},$$

where P_s = gauge pressure (psi) operating in series mode,

P_p = same, but parallel mode,

Tare = pressure of system w/o load,

Efficiency factor = 118.9 for series mode, 170.5 for parallel mode (provided by MARCO),

47.2 = flange height of main-purse drum (cm),

35.8 = flange height of bow-purse drum (cm),

m and b = distance from top of flange to top layer of cable (cm).

To determine line pull by this method, hydraulic pressures were recorded at the hydraulic pumps. New gauges had been installed prior to the cruise to ensure accurate pressure readings.

4. Skiff thrust during setting and pursing

To measure the force of the skiff thrust vector, a 6,750-kg (15,000-lb) dynamometer was attached between the skiff's towing bitt and the towline. Measurements were taken of the force required to tow the bow ortza [1] as the seiner set the net. Forces required to prevent the seiner from being pulled into the net were monitored throughout pursing and net rolling.

D. Results

1. Mesh shapes and tensions

The mesh shapes were photographed and mesh tensions were measured by SCUBA divers on three sets (2, 4, and 5). During Set 2, the measurements were made in the stern-bend area of the net. The divers entered the water about 5 minutes before pursing was completed and collected measurements and photographed the webbing at the top of each strip, starting from the corkline and ending at the top of the seventh strip. At the seventh strip, the net had started to shallow up to where the rings were being attached to the seiner's ring stripper. The maximum depth recorded was 22.9 meters (75 ft). Mesh tensions varied between 0 and 0.7 kg (1.5 lbs) with no apparent trend. The mesh angles (angle formed by the two bars descending from the knot at the top of individual meshes) became more acute with depth (Table 5).

During Set 4 the measurements of the webbing were made at the mid-net zipper. The divers entered the water just as pursing started and made the measurements during the first half of pursing. The mesh tensions were higher in the first two strips but were reduced somewhat in the remaining strips. Mesh angles did not change appreciably with depth. The measurements were terminated at the seventh strip at a depth of 39 meters (130 ft- maximum depth allowed by NOAA Diving Regulations).

Measurements of the shapes and tensions of the fine mesh that forms the apex of the backdown channel were made during Sets 4 and 5. The measurements on Set 4 were collected just after net rolling started (4 to 11 minutes after rings up), and the measurements on Set 5 were collected just prior to backdown (20 to 27 minutes after rings up). It was not possible to make the measurements during backdown because of the strong current flow in the backdown channel.

The mesh tensions and angles were similar during Sets 4 and 5 even though the time and net configuration and volume differed greatly. The mesh angles recorded just after net rolling had

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[1] An ortza is a metal triangle at the bow and stern ends of the net.

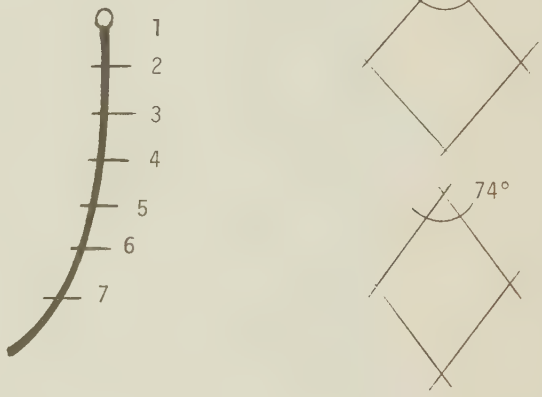
Table 5. Mesh Tension and Angle Measurements

Stern One-quarter Net (Set 2)

Strip No.	Tension Grams	Time from Rings Up*	Mesh Angle	Depth Meters
1	-	-2	87°	1.3
2	570	1	82°	12.2
3	300-570	3	-	-
4	150	5	-	18.3
5	150	7	63°	21.4
6	0-150	8	35°	22.9
7	150-570	10	29°	21.4

Mid-net Zipper (Set 4)

1	1140	-21	-	1.5
2	570-1140	-19	83°	12.2
3	1140	-17	77°	16.8
4	1140	-16	65°	24.4
5	610	-14	-	30.5
6	300	-	74°	-
7	230	-11	-	39.7

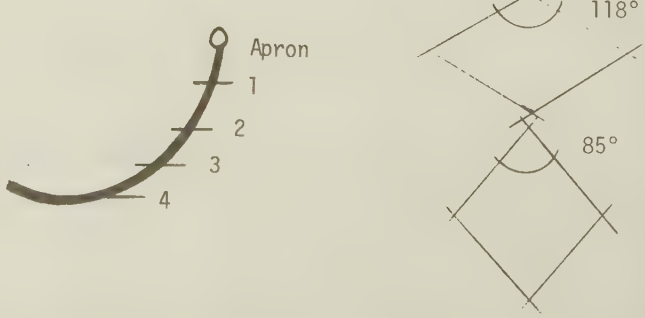


Backdown Apex (Set 4)

Apron Extension	0-570	4	87°	ø
1	300-570	8	97°	9.2
2	150-300	10	89°	15.3
3	150-370	11	93°	19.8

Backdown Apex (Set 5)

Apron Extension	0-570	20	118°	0
1	300-570	23	100°	9.2
2	150-300	24	114°	13.7
3	150-370	25	109°	19.2
4	-	27	85°	19.8



*"Time from Rings Up" indicates minutes before (minus) or after the rings break the surface of the water.

started (Set 4) ranged between 87° and 97°. During Set 5, just prior to backdown, mesh angles were slightly more oblique through the third strip (100° to 118°). The angle measured at the fourth strip was more acute and may have been due to the forces resulting as the boat started to back down. Mesh tensions ranged from zero to 0.7 kg (1.5 lb) in both sets and did not indicate any particular trend.

2. Surface configurations and bottom profiles of the net

a. Surface configuration of the net

The rates of change of the surface configuration of the net were estimated on five sets (1, 2, 3, 12, and 13). An idealized, composite view of the configuration of the net during the set sequence, prior to backdown, is shown in Figure 3. The 550 meters (300 fathoms) of corkline at mid-net between buoys 4 and 8 advanced toward[1/] the seiner at 7.1 meters per minute (range 4.7 to 14.4 m/min) during pursing. When pursing was completed and the purse rings secured to the stripper, the corkline and vessel essentially stopped advancing toward each other. The rate of "advance" varied between +3.5 m/min and -4 m/min and averaged +0.6 m/min. As net rolling began, the webbing in the stern bend was pulled aboard, rapidly reducing the net's surface area and volume. The mid-net area also stayed at a relatively constant distance during the first 183-274 meters (100 to 150 fathoms) of net roll.

Net retrieval rates were determined for one water set (Set 4) and three porpoise sets (3, 13, and 15). Retrieval rates for the three porpoise sets were 31.1, 38.4, and 37.7 m/min (17, 21, and 20.6 fa/min) respectively. These rates were determined for only the first half of the net rolled aboard prior to backdown. Post backdown net retrieval rate was usually the same as before backdown, i.e., full speed. Retrieval rate of the net during Set 4, the water set, was slower than normal because the crew was marking holes and damaged sections for mending after the set. Retrieval during the set averaged 18.3 to 20.1 m/min (10 to 11 fa/min).

b. Bottom profiles of the net

Bottom profiles of the net were obtained by running transects with a fathometer-equipped boat on five sets (1, 2, 5, 7, and 8). Eleven fathometer transects were run during pursing: two while placing the rings on the stripper and seven while the net was being rolled aboard the seiner. A complete summary of individual bottom profile sets, with recorded profiles and net locations is presented in Appendix C.

[1/] The corkline and the seiner advance towards each other at different rates; however, the rates are not measurable because there is no fixed point of reference. From the observers' perspective, the corkline advances towards the seiner.

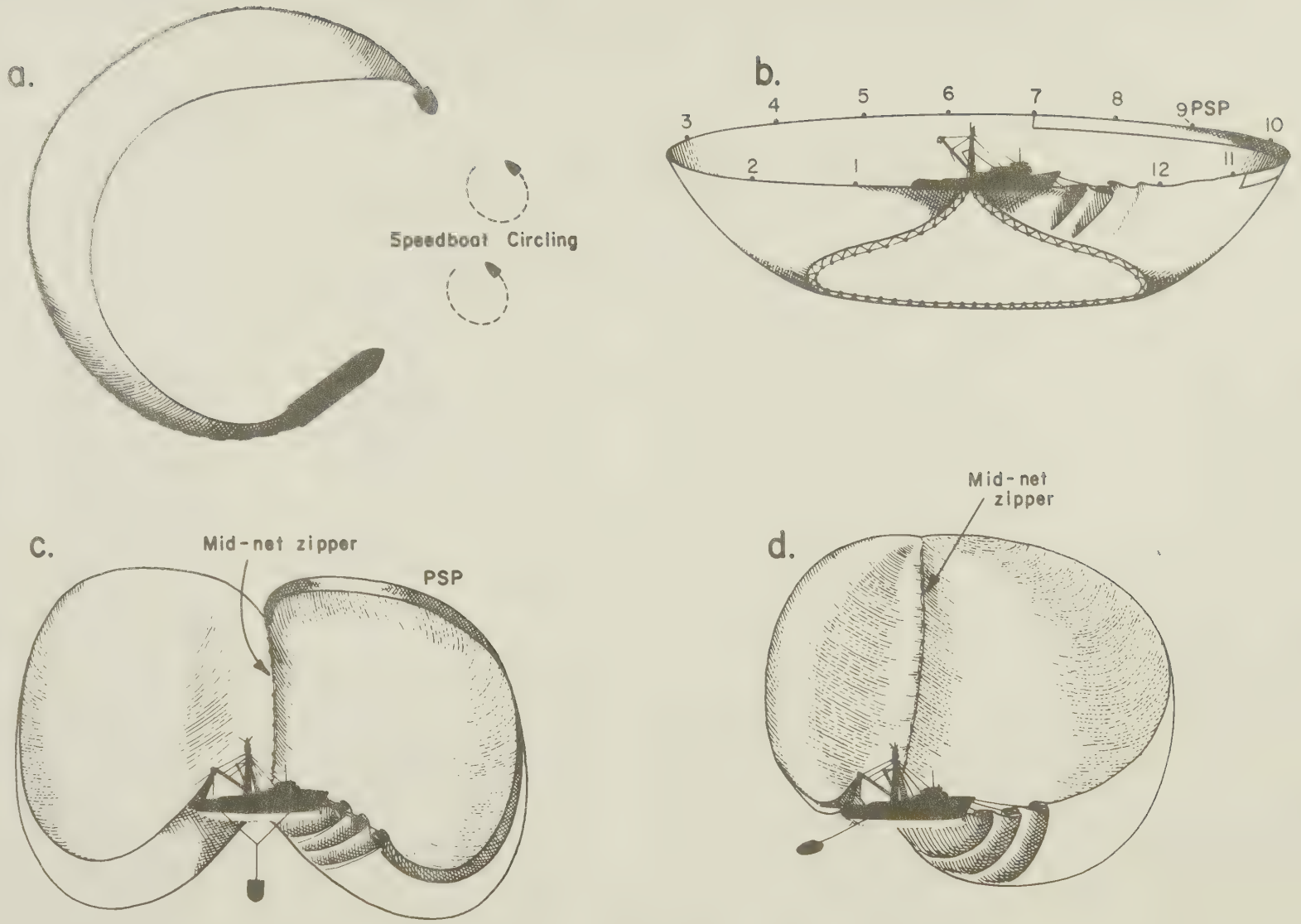


Figure 3. A composite view of the configuration of the net prior to backdown

a. Setting the net
b. Pursing (the net is about half pursed)
c. Rings up
d. Rolling the net

During pursing, maximum fishing depths of 47 and 44 meters (154 and 145 ft) were recorded when pursing was about half completed. The purse cable descended from the davit and away from the vessel at varying angles throughout the pursing operation. The angle was an estimated 45° from perpendicular at the start of pursing and was gradually reduced to perpendicular in the last minutes of pursing. The cables also angled away from each other at first, the stern cable leading toward the stern one-quarter net area and the bow cable toward the bow one-quarter net. In the last minute of pursing, this angle was reduced so the cables were parallel. Underwater observation showed that the depth of the purse cable remained fairly constant at first but began decreasing in the last half of pursing. Purse-cable sections closest to the vessel shallowed first, leaving the apex of the cable loop at the greatest depth. A comparison between repetitive transects to show the rate of rise during pursing (as in Set 8; T, 1 to 3) is not possible, since repetitive transects were not exactly duplicated. Similarly, retrieval rates from known depths were not possible because the exact recording location on the cable could not be identified. The ascending rings approximated the speed of purse-cable retrieval (8.5 m/min.) during the last minute(s) of pursing. The true ascent rate was somewhat slower because the rings were still sliding back toward the cable apex loop.

The profiles also showed that the mid-net zipper area began to rise, forming a shallow bulge during the last half of pursing. The shallower mid-net area rose to about 31 meters (102 ft) before the completion of pursing, the result of increasing tension along the zipper between the leadline and corkline.

Profiles obtained after pursing but prior to net roll showed that the mid-net zipper bulge varied between 13 and 32 meters (43 to 105 ft) during this period (Figure 3c). Deeper areas formed on either side of the bulge as the bow and stern bends developed. The stern bend tended to be deeper, with profile depths 20 to 48 meters (65 to 157 ft). Maximum depths in the bow bend ranged between 20 and 28 meters (66 to 92 ft).

Profiles obtained during the net rolling procedure showed that the deeper area of the stern bend was eliminated in the first 4 to 6 minutes (Figure 3d). Depth of the bow bend ranged between 15 and 27 meters (49 to 89 ft). The mid-net bulge ranged 13 to 22 meters (43 to 72 ft). When the mid-net zipper was rolled aboard, the net was tied down and backdown started. Profiles were not attempted during backdown because of the risk of forcing porpoise into the webbing.

c. Net configurations and profiles during backdown

Underwater observations were made during backdown on 5 sets (3, 5, 7, 8, and 9). The composite observations indicated that several dynamic factors, working together, resulted in what is generally termed "stern sway" (Figure 4). This subsurface net configuration occurred along the stern side (side attached to vessel's stern) of the backdown channel and was the result of the net's being pulled through the water. The stern-sway condition usually developed into a deep canopy which posed a serious threat to any porpoise in that area. Additionally, this canopy often collapsed against the rising floor of the backdown channel. During this cruise, however, no porpoise were known to have died in this type of canopy.

The first signs of stern sway were observed when the corkline and webbing had taken a strain from the vessel moving backward. As the vessel began each backdown, the surface and sub-surface configuration changed rapidly. The pull of the vessel had its greatest effect on the corkline (particularly the stern side), and along the webbing that made the channel floor from the rings to the corks at the apex. As the vessel swung around in a broad arc, the stern corkline was dragged across the water surface. The webbing from this side of the developing channel was pulled vertically towards the surface and then across, forming a shelf just below the surface.

The top two strips of small-mesh (1¼-inch) webbing in the backdown channel were greatly affected by the flow of water, but the 4¼-inch web below was not. The 1¼-inch mesh along the stern side offered a greater resistance to water flow and generally gave the appearance of being "blown" or washed into the developing channel. Adding to this effect were the slack sides (channel walls) from the rising channel floor. As the vessel moved backward, tension increased down the meshes of the channel floor from the rings (on the stripper) to the apex corks. This tension was greatest down the meshes between the extreme apex corks and the purse ring (the 27th from bow side) directly opposite those corks. Webbing in the area on either side of the number 27 ring had less tension

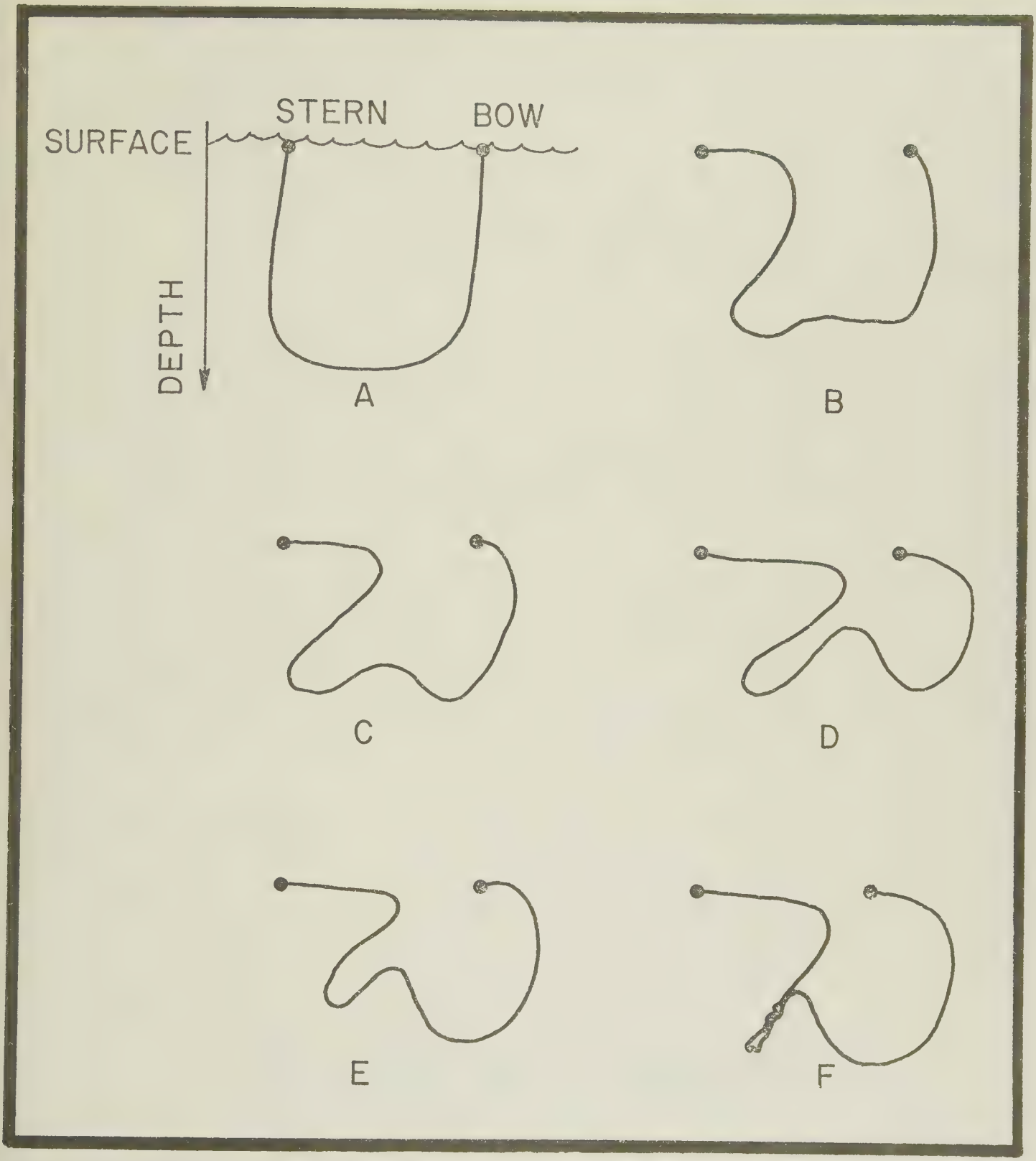


Figure 4. Cross section of the backdown channel showing the development of stern sway (as viewed from the seiner to the apex)

because the corks opposite that webbing were closer to the vessel. The amount of webbing between each cork and the lead line, to which the bridles and rings were attached, is the same except in the porpoise apron area. The Queen Mary's apron was 1 1/3 strips deep at the apex and tapered down to zero at 82.3 meters (45 fathoms) from each side of the apex (standard super apron). Generally, however, the closer the corks were to the vessel, the more slack in the webbing. The webbing along the ring-to-apex-cork axis had the greatest tension and was pulled up to a shallower depth, forming a mid-channel ridge with deeper areas on either side.

Along this mid-channel ridge, the meshes changed shape (from having horizontal to vertical axes) during stern-sway development. This change in shape tended to increase the depth of the webbing and was most evident along the channel floor, from the vessel to about three-fourths of the way down the channel. The meshes in the last one-fourth of the channel and apex remained open throughout backdown, presumably because of the stretched "hang in" at the corkline which distributed the forces of vessel pull and water flow at the apex.

This ridge along the center of the channel floor left a deeper "bagging" area on either side. The entire floor rose vertically, including the bags on either side of the ridge. This made the webbing on the sides of the backdown channel increasingly slack and subject to the effects of water flow as backdown proceeded. During the first stages of backdown, while the stern corkline was pulled across the water surface, webbing was fed upward from the bagging stern side of the mid-channel ridge. This also reduced the size and depth of the stern side bag (Figure 4, c through f).

As the mid-floor ridge continued to rise and the webbing from the stern wall moved upward, the stern side bag often collapsed vertically when the rising floor came in contact with the stern side wall (Figure 4, f). When this occurred, the backdown channel existed between the canopied stern-wall/ mid-floor ridge, down the bow side into the bagging area and up the bow wall of the channel. Webbing was also observed feeding up from the bottom of the stern bag over the ridge and down into the bow side bag, increasing the rate at which the stern side collapsed. The web along the bow side of the channel from the bunches to the apex also formed a minor canopy extending out and away from the channel. This area remained fairly wide but usually rose to approximately 4.5 meters (15 ft) deep at the end of the backdown procedure.

After release of all porpoise, the vessel continued backing around until the wind was again from the port side. The third bunch was released during this time and allowed to straighten out. The net still remaining in the water was rolled aboard and the tuna catch loaded into the wells.

3. Pursing rates and pursing forces

a. Pursing rates

Purse-cable retrieval rates were obtained during Sets 12, 13, and 15. In Figure 5, pursing rates are plotted relative to the elapsed time since the stern ortza came aboard.

Retrieval rates were 22.9 to 25.6 m/min (12.5 to 14 fa/min) during the first 10 minutes of pursing. This slowed to 17.4 m/min (9.5 fa/min) in the next 5 to 7 minutes. During the initial stages of pursing, the corkline bears much of the weight of the leadline. In the latter stages of pursing, the weight of the leadline is borne by the purse cable. For additional torque, the pursing mode was switched from series to parallel (arrangement of the hydraulic pumps which allows for greater torque or speed). This usually occurred 14 to 18 minutes after the stern ortza was attached. In the parallel mode, retrieval rates slowed to about 15.5 m/min (8.5 fa/min). During the final stages of pursing, the cable occasionally slowed to a stop as the boat rolled away from the net. At this time, the winch was pulling against the entire weight of the leadline plus the downward force on the web of gravity and drag resistance.

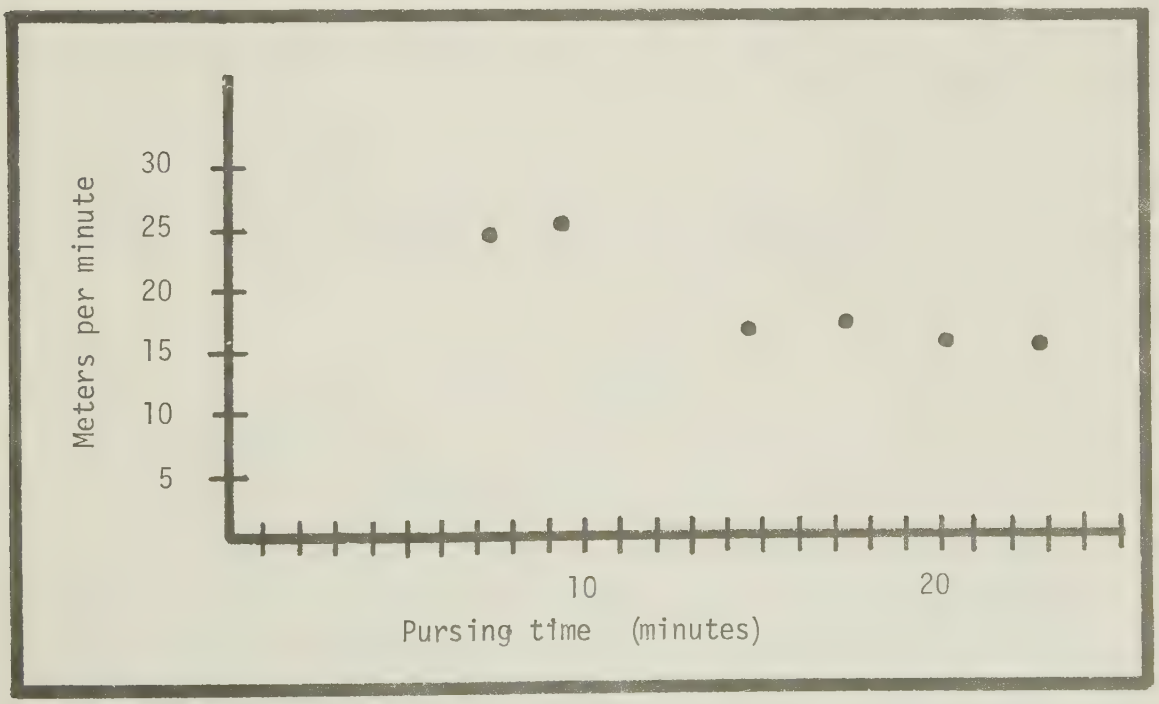


Figure 5. Pursing speed versus time

b. Pursing forces

Pursing forces were determined by measuring the tension of the purse cable with a dynamometer or by calculating the line pull from the hydraulic pressures. Dynamometer measurements were made on three sets (12, 14, and 15). The data are shown in Table 6. The measurements showed variability among sets and generally increasing tensions throughout pursing. Maximum tensions recorded on the bow cable during Set 13 were recorded as jerks instead of maximum working tensions. Working tensions were recorded during Sets 14 and 15. A jerk of 13,700 kg (30,445 lb) occurred just before rings up in Set 13. Maximum working tensions recorded during this set were almost double those on Sets 14 and 15. Working tensions of 5,831 and 6,375 kg (12,828 and 14,025 lb) were recorded during Sets 13 and 15 as the rings came out of water. With pursing stopped and only the weight of the leadline, those tensions fell to 2,830 kg and 2,603 kg (6,289 lb and 5,784 lb) respectively. Doubling these figures gives the total weight of the leadline at the time of rings up, a figure reasonably close to this seine's estimated leadline weight of 6,075 kg (13,500 lb). The weight of new materials required for an identical leadline were used for this estimate and does not include a weight loss factor resulting from wear.

Pursing pressures to calculate line pull were recorded during Sets 11, 12, 13, and 15 (Table 7). Under normal pursing conditions, the hydraulic pumping system ran at a constant and near maximum operating limit. Hydraulic line pressures under normal pursing conditions varied considerably between sets, but were fairly constant during any given set. Line pull generally did not increase with time. The winch speed, however, decreased during the last half of pursing, and the winch was always shifted into the parallel mode (low-speed, high-torque) during the last third of pursing. Line pull increased from about 2,700 to 3,825 kg (6,000 to 8,500 lb) in the first half of pursing to 3,600 to 4,050 kg (8,000 to 9,000 lb) just before rings up. A maximum pull of 5,120 kg (11,264 lb) was recorded during Set 13, just as the rings came out of the water.

4. Measurements of skiff towing forces

Measurements of the skiff thrust required to tow the stern ortza of the net and to tow the seiner were made during Set 12 (Table 8). As the seiner completed the circle while setting the net, the skiff maintained a pull of 900 to 1,800 kg (2,000 to 4,000 lb) and averaged 1,588 kg (3,500 lb) (Figure 4a). After transferring the ortza and attaching the bowline on the seiner's starboard side, the skiff maintained a pull of 900 to 2,925 kg (2,200 to 6,500 lb) during pursing (Figure 4b). Most of this time was at a continuous speed (1,700 rpm) with only minor changes in power and direction of pull to adjust the vessel's

Table 6. Pursing forces calculated from cable tensions (cable tensions were measured with a dynamometer)

Set No.	Purse Mode	Time*[1] (min.)	Cable Tension (kg.)	Winch Line Pull (kg.)	Estimated Line Pull at Water Surface [2]			
					Ø	∝	β	Line Pull (kg.)
13 [3]	Series	12	681	4296	8.5°	25°	30°	4349
	Series	15	908	5831	8.5°	35°	15°	5528
	Series	16	908	5831	8.5°	35°	15°	5528
	Parallel	20	908	5831	8.5°	45°	0°	4845
	Parallel	20.5	908	5831	8.5°	45°	0°	4845
14 [3]	Series	8	590	2853	11°	25°	30°	2818
	Series	11	499	2377	11°	25°	30°	2343
	Series	15	636	3090	11°	35°	15°	2866
15 [4]	Series	9	454	1687	14°	25°	30°	1605
	Stopped	16	409	1500	14°	35°	15°	1286
	Series	18	681	2625	14°	35°	15°	2250
	Parallel	21	908	3563	14°	45°	0°	2573
	Parallel	22	1589	6375	14°	45°	0°	4604

[1] Time in minutes after stern end of net (ortza) arrived at seiner.

[2] Angles ∝ and β were estimated not measured.

Pursing Time	∝	β
0-7 min	15	45
8-12	25	30
13-18	35	15
>19	45	0

Ø is the angle of the depression of the cable.

[3] The measurement was made on the bow purse cable during Sets 13 and 14.

[4] The measurement was made on the stern purse cable during Set 15.

Table 7. Pursing forces calculated from winch hydraulic pressures

Set	Pursing Mode	Time[1/] (min)	Line pressure (PSI)	Line Pull (kg)
11	Series	3	2100	4329
	Series	13	2000	3427
	Parallel	15.5	1400	2954
	Parallel	18	1750	3842
	Parallel	20	2000	4553
12	Series	0	1625	3400
	Series	6	900	2811
	Parallel	14	1500	3313
13	Series	12	1900	3912
	Series	16	2200	3709
	Parallel	20	1600	3614
	Parallel	20.5	2100	5120
15	Series	9	1650	2847
	Series	18	1750	2781
	Parallel	21	1650	3624

[1/] Time in minutes after stern end of net (ortza) arrived at seiner

Table 8. Net skiff pulling forces

Time	Engine RPM	Skiff Pull (kg.)	Comments	
1154	1600	900-1800	Towing ortza prior to transfer to seiner	Fig. 4a
1200	1700	1800	Skiff begins towing seiner	Fig. 4b
1202	1700	900-2745	Pursing full speed	
1207	1450	2025	Pursing full speed	
1214	1950	2925	Pursing switched to parallel mode	
1220	1800	1440-2295	Rings up	Fig. 4c
1228	1950	1710-4950	Rolling net aboard-towing from stern	Fig. 4d
1237	1950	2250-3510	Skiff directed to "pull hard"	
1251	2000	1710-3690	Towing hard astern	
1300	2000	1890-4140	Towing hard astern	
1305	1950	1440-4050	Towing hard astern	

orientation to the wind or sea conditions. After pursing was completed, the towing point on the vessel was moved to the stern to counter the pull of the net being rolled aboard (Figure 4d). Engine rpm and line pull increased to an average of 1,800 to 2,000 rpm and 1,452 to 4,082 kg (3,200 to 9,000 lb). A maximum of 4,950 kg (10,900 lb) was observed during net roll. The measurements collected during this set are subject to many variables, including wind and weather conditions, roll and pitch of both the seiner and net skiff, hull drag, pursing speed, and net-rolling speed.

E. Discussion

1. Mesh shapes and tensions

Throughout the net, mesh tensions averaged about 500 gm (1.1 lb). There were no apparent trends in either depth or location. Highest tensions (1,360 gm) occurred in the top two strips, near the mid-net zipper, just after the start of pursing (Set 4). At this time the leadline was at an undetermined depth well below 40 meters. Mesh tensions in this area were, on the average, a little higher than elsewhere, but their ranges overlapped with other areas measured. The mesh tensions near the zipper have the most tension from the forces of pursing because this portion of the net is the furthest from the seiner.

Mesh angles observed in the stern area of the net at the start of net roll (Set 2) showed decreasing angles with increasing depth. Corresponding tensions did not increase with decreasing angles. The reduction in mesh angles probably occurred during the final minutes of pursing, and the angles simply maintained their shape after the completion of pursing. There were no major forces on the webbing at this time since pursing was completed.

Tensions measured at the backdown apex, just after net roll started, and measured again prior to backdown, were almost identical. Wider mesh angles recorded just before backdown were probably due to increasing horizontal forces resulting from the action of the net skiff pulling the seiner and net backwards in preparation for backdown.

Measurements prior to backdown presented no problem to the researcher/diver. Once the seiner began to back down, however, it became impossible to measure and photograph the meshes without deforming whole areas of webbing while attempting to maintain a given position. Underwater observations during backdown clearly showed the meshes change from wide open at the apex to tightly closed along the mid-channel floor. It was believed that the meshes were held open at the apex by (1) the force and orientation of water flow down the channel and (2) the stretched "hang-in" rate in the backdown apex. Along the channel floor (and away from the apex) the meshes were pulled tight by the vessel backing. Meshes remained open as the

walls of the channel became slack during backdown. Additionally, these meshes in the channel walls were pulled from the side as the vessel backed down.

It is important to recognize that, during the initial stages of backdown, the meshes along the channel floor were pulled tight by the vessel backing down. The effect of this is a major change in the sub-surface configuration of the backdown channel. It is also an important factor in the development of stern sway and canopy formation (see stern sway and canopies, paragraph IV.E.2.c., "net configurations and profiles during backdown").

The measurements prior to backdown satisfied the basic requirements for simulation and supported general opinion on purse seine dynamics. A more detailed and refined study of mesh shapes and tensions would certainly yield useful information. Time and resources needed for a full scale diving operation, necessary for such a study, are not warranted at this time and no further studies are planned.

2. Surface configurations and bottom profiles of the net

a. Surface configuration of the net

The purse seine was normally laid out in roughly the shape of a circle. This shape varied somewhat depending on the porpoise response to the herding efforts of the speedboats and vessel. Usually 50 to 150 fathoms of towline was let out in completing the circle. When the circle was completed and the bow ortza was transferred back to the vessel, the winchman started hauling in the stern ortza with the tow cable, normally using only the stern purse drum until the ortza was retrieved.

With the stern ortza just in and the corkline stretched tight, the surface area measured approximately 83,606 square meters.

$$d = \frac{c}{\pi} = \frac{1025m}{3.14} = 326 \text{ m}$$

$$A = \pi r^2 = 83{,}606 \text{ m}^2$$

As pursing continued, the mid-net area of the corkline (approximately 300 fathoms between buoys 4 and 8) was pulled toward the vessel by the pursing action. Although the seiner was also pulled into the net, the action of the net skiff, towing on the stern starboard side, served to offset much of its effect. The 100 to 150 fathoms of corkline at either end of the net did not move toward the vessel but rather changed shape forming bends at the seiner's bow and stern. The three bow bunches were always pulled during the first half of pursing, reducing the length of corkline by approximately 87 fathoms and reducing the surface area within the net. Additional reduction in surface area occurred when the corkline became slack and wrinkled during pursing. These actions

reduced the surface area by approximately one-half to two-thirds (42,000 to 28,000 square meters) by the start of net rolling.

The net was rolled aboard at about 38 meters per minute, and it took an average of 18 minutes to reach the backdown point. The surface area was reduced to approximately 2000 square meters at the start of backdown.

b. Bottom profiles of the net

The fathometer proved very useful in ascertaining the net's topography during pursing and net roll. Attempts to measure the sinking rate of the leadline were unsuccessful because it was difficult to determine the exact depth and position of the leadline. No attempt was made to use the fathometer during the backdown maneuver.

The maximum recorded fishing depth of the Queen Mary's seine was 47 meters (154 ft) when it was about half pursed. The leadline may have gone somewhat deeper in the first few minutes of setting and retrieving the towline. The winch brake is always set for a slight tension on the cable during setting to prevent a backlash. This strain prevented the leadline from sinking to the fullest extent.

Bottom profiles showed that the leadline remained at about 40 to 45 meters at the start of pursing and began to shallow in the last half of pursing. The mid-net area of the corkline being farther from the seiner during pursing had the greatest amount of tension on the webbing. The corkline in this area was pulled toward the seiner at 7.1 meters per minute. The increasing tension on this webbing caused the mid-net area to shallow more rapidly than the areas on either side (i.e., bow and stern bends). This mid-net bulge rose throughout pursing and eventually maintained a depth ranging between 13 and 32 meters (43 to 105 ft).

As the mid-net area of corkline and the seiner advanced toward each other, the 30.5 to 45.8 m (100 to 150 fa) of corkline on either side became slack and wrinkled. These two areas formed the bow and stern bends around the seiner. The formation of these bends is a natural result of pursing the bottom of any long, shallow (less than 12 strips) net. The webbing in the center of the net was pulled tight, while areas closer to the vessel, with the same aount of web, remained slack. The stern bend was generally deeper (20 to 48 m) than the bow (20 to 28 m). Once net rolling began, however, the stern bend was rapidly eliminated leaving the bow bend as the deepest part of the net.

Three bow bunches, totaling about 159 m (87 fa), were always pulled in during pursing. The web under these bunches hung very loose and allowed a deep pocket to form immediately below the bunches. Divers observed this deep pocket on at least three occasions

and found its bottom depth varied between 21 and 31 meters (80 to 100 ft). As backdown started, this pocket on two sets was absorbed into and became part of the channel. On one occasion the pocket collapsed and folded under the backdown channel. While no porpoise mortality was observed in this area, it appears to have a high kill potential, particularly if the seiner backs down too rapidly at the start.

c. Net configurations and profiles during backdown

Reducing the formation of canopies and stern sway in the backdown channel may have the greatest short-term effect on reducing porpoise mortality. Observer data collected in 1978 shows that 39.1 percent of all porpoise mortality (unpublished data) occurs in deep canopies along the stern side of the backdown channel.

The primary factors involved in this dynamic process of stern-sway formation and its subsequent development into a deep canopy are:

(1) Pull of the corkline across the water surface as the vessel begins its backdown arc.

(2) Differential resistance to water flow between the small-mesh, porpoise safety panel and larger (4¼-inch) webbing below.

(3) Rise of the backdown channel floor that forms a mid-channel ridge.

(4) Presence of slack and excess web on both sides of the channel.

(5) Rotation of webbing into the bow-side bag, resulting in reduced size of the bag formed on the stern side of the mid-channel ridge.

Formation of a stern canopy results naturally from pulling a large bag of webbing through the water in a gentle arc. While a complete solution to the problem is not immediately recognizable, these underwater observations will assist in the design of various net and procedural modifications to reduce the effect of stern sway.

Some operational procedures just prior to and during backdown can effectively reduce the severity of stern sway and related canopies. Basic to any smooth, effective backdown are (1) having the proper amount of corkline and net in the water, (2) using the net skiff to pre-form the backdown channel, and (3) controlling the turning radius of the backdown arc.

The amount of corkline necessary is directly related to the depth (number of strips of webbing) of the net. The deeper a net, the more corkline necessary for proper deployment. Other factors include the amount of webbing "hung in" to that section of corkline, the arrangement of bunchlines, and the size and shape of the seiner's hull. Once tiedown points have been determined, the vessel operator must ensure that the exact same tiedown points are used in each set.

Using the net skiff to pull off the seiner's starboard stern quarter just prior to tiedown was effective in reducing stern sway. Use of the net skiff at this time pre-forms the backdown channel and reduces the lateral pull of the corkline along the channel's stern side. The seiner's main engines were also occasionally engaged momentarily to assist in pre-forming the channel.

The turning radius (backdown arc) in which the seiner backs down must be carefully controlled. Too tight an arc increases the lateral pull of the corkline and channels the water flow out the bow side of the backdown channel instead of out the apex. Backing down in a straight line causes a premature collapse of the channel. The seiner's rudder was ineffective in adjusting the backdown configuration while moving in reverse. The backdown arc was easily adjusted, however, by using the bow thruster and/or the net skiff. The net skiff normally runs straight off the vessel's stern so that it can pull the seiner's stern either way as directed by the captain. Once backdown begins, it is essential to maintain a slow, steady speed until the channel is fully formed. This allows the floor of the channel to rise slowly, giving the porpoise more time to move away from the stern sway and into the channel's apex. Starting slowly may also allow the deep bag, under the bunches, to be incorporated into the channel rather than being folded under, as was observed on one occasion.

3. Pursing rates and pursing forces

   a. Pursing rates

The rate at which the net was pursed varied throughout the pursing operation. The winch normally ran at full operational speed until the cable was retrieved and the bottom of the net was closed and secured onboard the vessel. The winch could be slowed or stopped whenever conditions warranted. Additionally, currents, wind velocity and the pull of the skiff influenced the pursing rate. Pursing speeds were faster and cable tensions least at the start of pursing. Retrieval rates decreased as purse cable tensions increased from the combined forces of net drag and the weight of the leadline.

Retrieval rates of 25m/min in the first 10 minutes of pursing fell to 15m/min at the end of pursing. In the last minute(s) before the rings came out of water, the pulling action of the winch occasionally stopped from increased tension as the seiner rolled away from the net. When the seiner rolled toward the net, line speed increased.

b. Pursing forces

The forces required to purse the net (line pull) were determined by two methods. One method used hydraulic line pressures and an efficiency factor (provided by the manufacturer) to calculate line pull. Pursing forces recorded in four sets varied between 2,724 kg and 3,946 kg in the first 10 minutes of pursing. These forces increased to about 3,629 kg toward the end of pursing, with readings of 4,536 kg to 4,989 kg as the rings came out of the water.

Manufacturer specifications for this particular winch show the maximum full drum line pull, in series mode, to be 4,126 kg for the main purse drum, and 5,670 kg for the forward drums. Pursing in the parallel mode doubles these forces. The forces required to purse the net used on the Queen Mary exceeded the winch pull occasionally in the last few minutes of pursing when the seiner rolled away from the net.

There were two primary problems affecting the accuracy of this method of determining line pull. The first was the overall efficiency factor of the hydraulic system. This factor was estimated for both series and parallel pursing modes by its builder (Marine Construction Corporation (MARCO), Seattle, Washington). While this figure is probably very close, the hydraulic system on the vessel was 9 years old, and the true level of efficiency may be somewhat lower than the MARCO estimates.

The second problem was in determining the amount of torque provided by the winch relative to the amount of cable on the pursing drums. The more cable on the drums, the greater the distance from the center of the drum (drive center) and, subsequently, the less torque. For this cruise, the amount of cable was determined by subtracting the free and uncovered flange from the total drum diameter. Figuring cable length by this method involved a problem because the cable tended to be laid down unevenly. The M/V Queen Mary's winch is equipped with a manual "level wind" operated by the winchman, but when other duties demanded his attention, the cable tended to mount up on one side or the other. Uneven winding resulted in fairly rough flange measurements which reduced the accuracy of the basic line-pull measurements.

The other method of determining line pull was not subject to these uncertainties and is considered more accurate. These measurements reflect actual tensions exerted on the purse cable. They are not directly comparable with the total line pull, required at the winch, to purse the net.

Cable tensions recorded during Set 13 were the highest observed tensions, not average working tensions. Average working tensions recorded in Sets 14 and 15 showed the cable tension increasing rapidly during the last half of pursing. As the tension increased to nearly 3,632 kg in the last minutes of pursing, the line speed dropped to 15 m/min. A tension of 6,365 kg was recorded (Set 15) as the rings were pulled out of the water.

Tensions exerted on the purse cable entering the water from the purse davit were calculated from line tensions at the winch. The angles of purse block deflection and of the cables entering the water were estimated and not precisely measured. While these data may be soft in that respect, they are probably closer to the actual forces on the purse cable.

4. Measurements of skiff towing forces

The skiff's towing force on the net and seiner was measured during Set 12. Wind and sea conditions were mild, and the fishing operation was normal in all respects. Once released from the seiner, the skiff maintained a light strain on the net while the seiner completed its circle. After the ortza was transferred to the seiner, the net skiff moved to the starboard side and attached the towline. A towing bridle was used for greater effectiveness in maneuvering the seiner.

Towing forces were varied during pursing to prevent the seiner from moving into the net and collapsing it. The towing force was reduced occasionally when the corkline on the far side of the net sank too much from the combined forces of towing and pursing. When the rings came up, the towing force was also reduced so the rings could be put on the ring stripper. The bow side of the skiff's bridle was also disconnected to more effectively counter the sternward pull of the seiner during net rolling. The greatest pulling force (4,950 kg) of the skiff was recorded at the start of net roll when it was necessary to clear the stern bend webbing from the seiner's propellers. Once net rolling was underway, the skiff maintained a strong, steady pull of 2,000 to 4,000 kg off the seiner's stern quarter (Figure 3d). As the tiedown point for backdown approached, the skiff was directed to pull hard astern. This maneuver was very effective in preforming the backdown channel and reducing the effects of stern sway.

While one set of measurements is not sufficient to draw firm conclusions, it is interesting to compare the skiff's towing forces to the pursing forces taken in Set 12. The pursing forces during Set 12 ranged between 2,722 and 3,311 kg (6,000 and 7,300 lb). During the same period, towing forces averaged between 998 and 2,945 kg (2,200 and 6,500 lb). While these measurements are not directly comparable, they do seem to indicate that the vessel was pulled

into the net by the pursing action. This situation is, of course, controllable by varying the pulling force of the skiff or pursing force of the winch. Both of these forces were varied from time to time depending on the net's surface configuration. The vessel's bow thruster was also used occasionally to aid in maintaining the desired configuration while the bow and stern bends formed around the seiner.

V. TRAINING FILM

A. Background

The tuna/porpoise management branch of NMFS has, among its other duties, the responsibility to conduct skipper workshops and to train and field the tuna/porpoise "observers". The tuna-seiner skippers must satisfactorily complete a formal training session to obtain an operator's certificate of inclusion. Training topics include: certificate holder responsibilities, provisions of the Marine Mammal Protection Act of 1972, marine mammal regulations pursuant to the Act, and instruction in fishing gear and techniques that are required or that will contribute to reducing the mortality of porpoise. The observers receive a month of instruction before they are sent out on the tuna seiners. The training includes purse seining technology, marine mammal identification, marine mammal regulation, data collection techniques and technology to reduce mortality. Movies and slides are used to enhance both types of training; however, there is no single movie that describes the porpoise set completely or details all of the porpoise safety gear and rescue techniques.

B. Objectives

The primary objective of Leg 2 was to film movie footage for a 20-minute training film. The training film will show normal purse seine operations, required porpoise rescue gear, and techniques. The film will be used to augment the NMFS skipper workshops and NMFS observer training sessions.

C. Methods

The filming was done with two Canon Scopic 16-mm movie cameras and Eastman Ectachrome Commercial 7252 film. A shooting script was followed. One cameraman filmed activities during Leg 1 (Sets 1 to 10 on an opportunistic basis, and two cameramen filmed activities during Leg 2 (Sets 11 to 15).

D. Results

Seven thousand feet of film were exposed. Running time of the raw footage is 3 hours, 18 minutes. Some filming was done in slow motion (64 frames per second) to adjust for camera movement.

All aspects of the tuna purse seine operation were documented. The pilot house, working deck, wet deck, cross-tree, speedboat, and net skiff were used as filming platforms to ensure adequate camera angles. To authentically depict crew-member activities and responsibilities, filming was done from the net skiff as the purse-seine net was deployed and from a speedboat during backdown. These sequences provide various crew-member views of the operation.

Gear maintenance and safety precautions were emphasized. Speedboat towing sequences were staged during Set 12. Four speedboats towed the net at designated towing points to maintain an open net to ensure porpoise safety. These sequences were filmed from the mast, pilot house, and a speedboat. Required porpoise gear and rescue procedures were filmed during backdown. Close-ups of rubber-raft use, facemask and snorkel use, and porpoise release were filmed from a speedboat attached to the apex of the super apron during backdown.

E. Discussion

All filming objectives were completed, and the film quality is good. An edited and narrated 20 to 30 minute film is in production as of June 1979. Some short animated sections were prepared at SWFC and will be cut in to enhance particular subjects which did not lend themselves to filming.

Some difficulties were encountered from the portable power supplies used for the cameras. One battery system could not supply enough power to operate the camera for more than four rolls of film. While this problem was minor and did not cause the loss of any footage, it was a nuisance.

A second minor problem was the amount of filming time lost while photographers changed film rolls. The 100 foot film rolls provide about 3-minutes projecting time. Future filming might consider the advantages of cameras accepting 200- to 400-foot rolls and equipped with back-up power supplies.

VI. PORPOISE BEHAVIOR

A. Background

Knowledge of the behavior of the tuna and the porpoise is basic to the development of any techniques or gear that will lead to a reduction in porpoise mortality. Thus, the overall behavioral goal on Cruise V was the accumulation of data and observations to elucidate the behavior of the tuna and porpoise.

B. Objectives

The objectives were to:

1. Observe the evasive techniques of the porpoise during the chase and set.

2. Observe the evasive techniques during aborted chase.

3. Observe the behavior of captured porpoise.

C. Methods

The behavior of the stocks of offshore spotted porpoise Stenella attenuata, and eastern spinner porpoise, Stenella longirostris, was observed at every opportunity during the course of the cruise. Observations were made from the vessel's deck, from atop the charthouse, from the cross-trees (observation platform below crow's nest), and, in the water, from a raft or while snorkeling. Observations on the vessel were made with 20-power and 7-power binoculars. Observations in the water utilized a two-man raft, face plate, snorkel, and swim fins.

D. Results

1. Evasive techniques during the chase and set

Porpoise schools were chased with speedboats 18 times during Cruise V. Twelve porpoise sets were made, and the chases were terminated six times because of the evasive behavior of the porpoise. The average length of a successful chase was 23.5 minutes, and the chase time ranged from 11 to 59 minutes. Six sets (9, 10, 11, 12, 13, and 15) were made on pure schools of spotters, and one set (7) was on a pure school of eastern spinners. The remaining five sets were on mixed schools (Table 2). On three sets (7, 11, and 12), all the porpoise chased were captured. On two sets (10 and 13), none of the animals were captured.

School size prior to the chase was estimated to range from 68 to 4,000 animals, averaging 768 animals. The sizes of the schools captured ranged from 0 to an estimated 1,200 porpoise and averaged 346. Thus, about 45 percent of the porpoise chased prior to the set were captured. The remaining 55 percent were not captured because of their evasive action or because they were deliberately excluded (cut out) from the set sequence.

Set log data indicates about 75 percent of the porpoise not captured had successfully taken evasive action to escape. The remaining 25 percent were intentionally "cut out" (Table 9). The porpoise evaded the set either during the chase or after the set was set, and before it was pursed. About 2,250 animals evaded capture during the chase and 2,068 evaded capture after the net was set. Evasive action resulting in escape of porpoise was observed during the chase on all but three sets (7, 11, and 12). Porpoise escaped after the set commenced on three sets (8, 10, and 13), and porpoise were intentionally "cut out" on two sets (8 and 14).

Table 9. Estimated number of porpoise that were not captured in each set

Set Number	Escaped During Chase		Escaped After Net was Set		"Cut Out"		Total Escaped	% of Original School
	Spotters	Spinners	Spotters	Spinners	Spotters	Spinners		
3	23	177	-	-	-	-	200	35
5	88	12	-	-	-	-	100	24
6	718	215	-	-	-	-	933	62
7	-	-	-	-	-	-	-	-
8	-	-	403	1031	819	580	2833	71
9	400	-	-	-	-	-	400	62
10	113	-	454	-	-	-	567	100
11	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-
13	20	-	180	-	-	-	200	100
14	480	-	-	-	-	60	540	90
15	4[1/]	-	-	-	-	-	4	5
TOTAL	1846	404	1037	1031	819	640	5777	63

[1/] Estimate of school size before the set was probably low

The term "cut out" of a set is not as definitive as it first appears, as some evasion might be involved. Conversely, some porpoise that appear to have evaded the net may have been cut out. Some reasons identified for cutting out animals were: (1) the school was too large or of an undesired species, (2) the portion of school believed to be carrying fish was encircled; (3) the porpoise did not respond to the chase and seiner tried to capture what were available; and (4) the school was too spread out. The latter two categories contained a strong element of evasion.

Schools, in which all the porpoise chased were captured, contained a single species. Set 7 was a school of eastern spinners, and the porpoise Sets 11 and 12 were all spotters. At the beginning of the chase/set sequence, the porpoise in these three schools responded in the same manner. The spinner school and the larger of the two spotter schools (Set 11) "ran" as tight units and were encircled in only 11 minutes. The school captured in Set 12 comprised two groups. The groups had been about a mile apart before the chase, and the chase brought them together. Both groups ran tightly together.

The seven sets where evasive action resulted in capture of some fraction of the animals present consisted of five mixed-species schools and two schools of pure spotted porpoise. Three basic behavior patterns during chase and encirclement were noted:

a. Hiding behavior

The porpoise lay low in the water with nearly imperceptible movement, as if hiding from the seiner and speedboats. The animals would then move out of the containment circle formed by the seiner and the speedboats (Figure 6). Behavior of this type was noted on four sets (3, 5, 9, and 14).

b. Backing-up behavior

The porpoise turned from the desired direction of travel (counterclockwise) and either ran between speedboats or dove under them. Both actions resulted in the porpoise breaking free of the containment circle (Figure 7). "Backing up" behavior was noted in two sets (6 and 15).

c. Escapement from net

After the set commenced and the seiner came around to meet the skiff, the porpoise dove under the seine to escape. This behavior pattern was noted during Set 8 where more than 1,000 spinners and 400 spotters escaped (Figure 8).

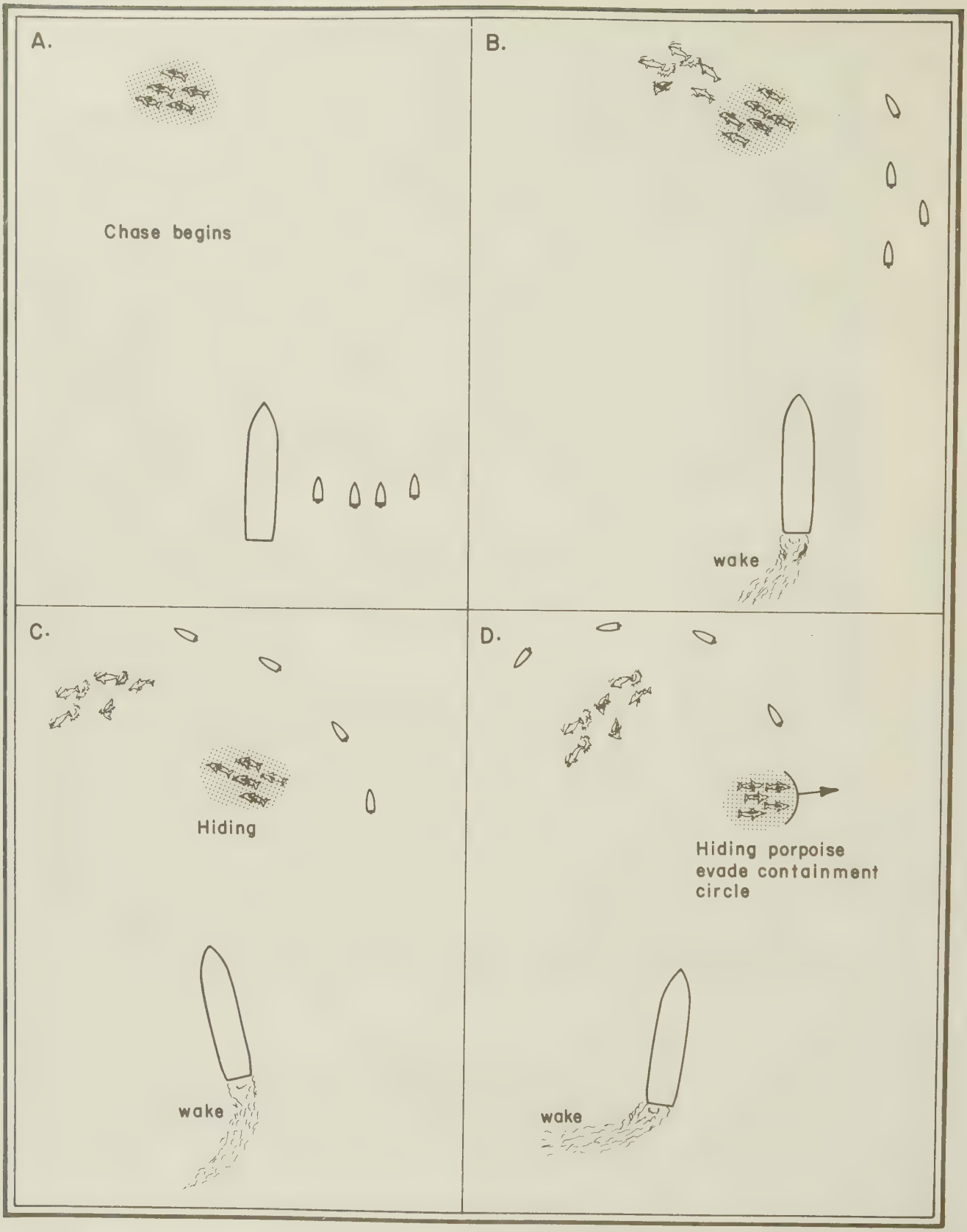


Figure 6. Porpoise chase sequence depicting hiding behavior as an evasive technique

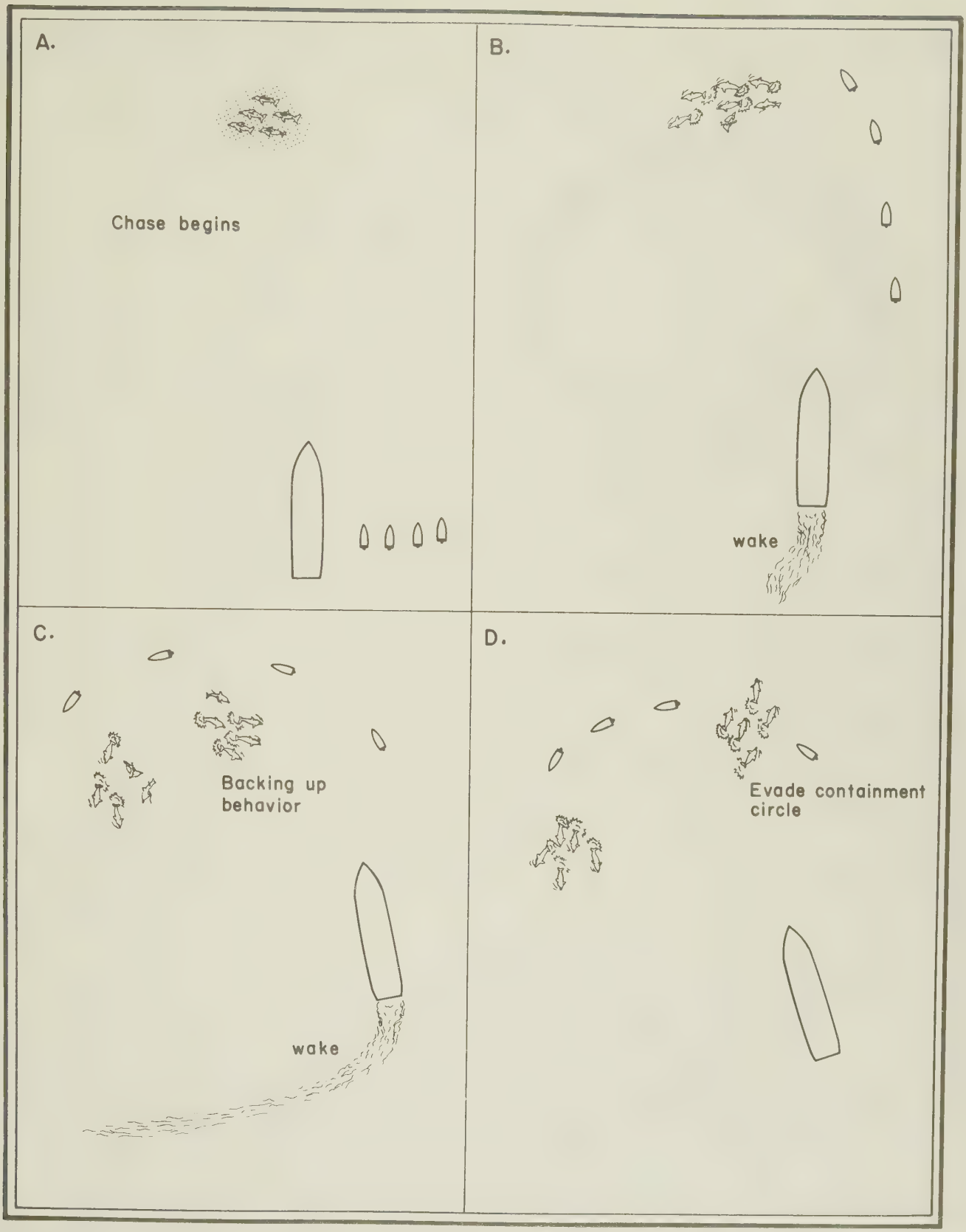


Figure 7. Porpoise chase sequence depicting "backing up" as an evasive technique

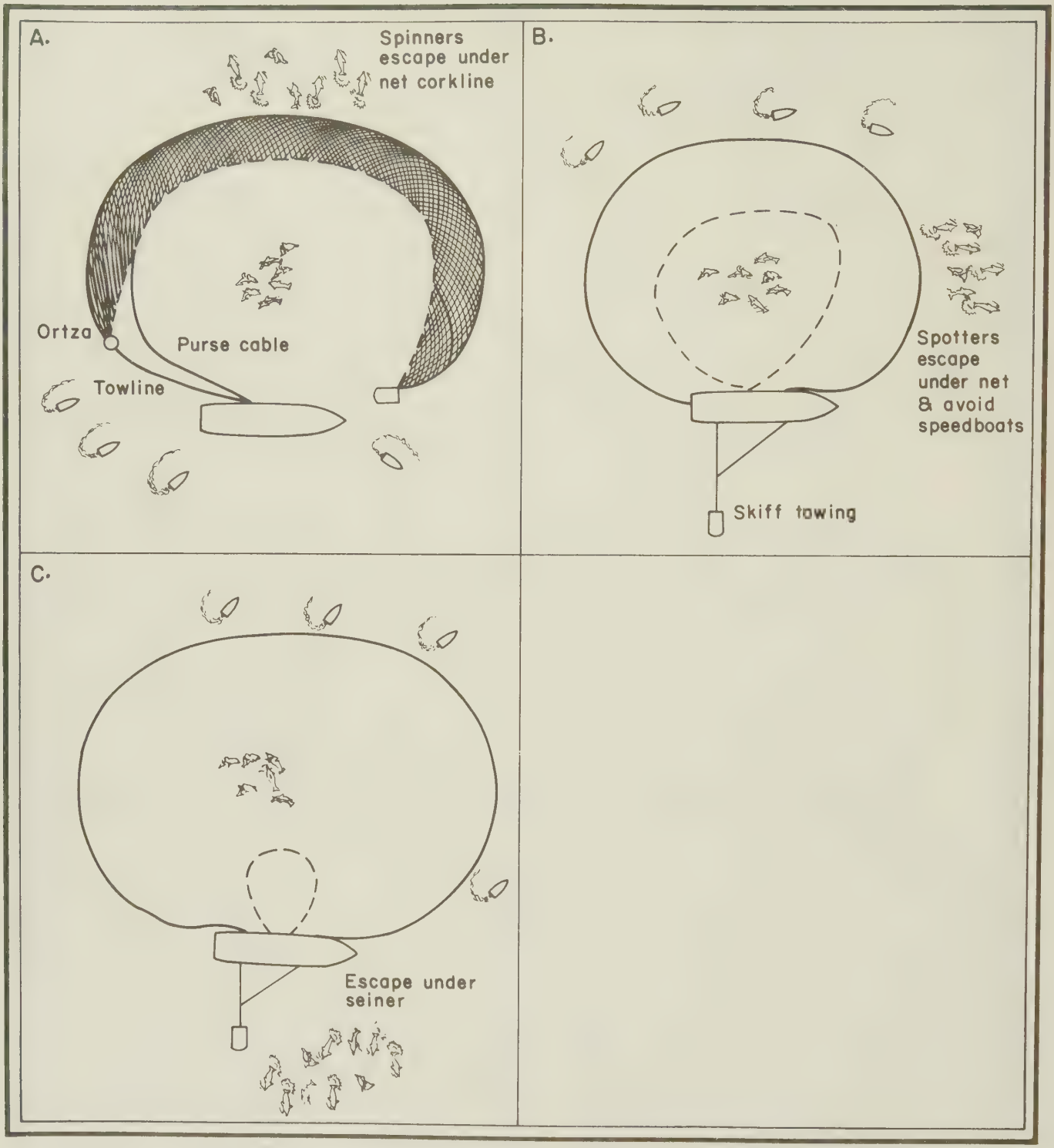


Figure 8. Porpoise set sequence showing the porpoise escaping from the seine by diving

On Sets 10 and 13, where no porpoise were captured, the schools were widely scattered before the chase commenced. When the chase for Set 10 began, the porpoise were scattered from the bow to 80° off the port side of the vessel, a distance of about 3.2 to 4.8 km (2 to 3 mi). During Set 13, the porpoise were spread in a line approximately 1.6 km (1 mi) long. In both cases, the porpoise used two evasive tactics: they remained low in the water and waited for the speedboats to pass, or they escaped after the net was set by running between or under circling speedboats.

2. Evasive techniques during aborted chases

An aborted chase is one in which the speedboats engage actively in the pursuit of a school of porpoise but the net is not set. Six chases (33 percent) initiated during the course of the cruise were aborted, all due to evasive action by the porpoise. In total, approximately 4,300 porpoise were involved in the six aborted chases. Four of the schools were pure (three spotted and one spinner), and two contained mixed species (Table 10).

One of these schools, the school of spinners, was lost in a rain squall. Once the porpoise entered the squall they could no longer be seen by the vessel captain, and the chase was aborted.

During four of the chases (1, 3, 4, and 6), the porpoise were scattered over a large area of about 3.2 square km (2 square mi), and at no time during the chase could a sufficient number of animals be bunched together to warrant setting.

During chases 2, 4, and 6, the porpoise did not respond to the herding efforts of the seiner and speedboats. On these chases, the porpoise lay low in the water and (a) did not run as the speedboats approached, (b) ran towards the speedboats and/or seiner, (c) rode the bow and stern wake of the seiner; or (d) performed a combination of these actions.

3. Behavior of captured porpoise

After capture, the porpoise would generally mill in the center of the seine. On Set 3, an estimated 200 porpoise (90 percent spinners and 10 percent spotters) milled in an area approximately 60 feet in diameter. About 25 minutes later, the same porpoise had shifted their position in the net from near the center to the stern bend where they occupied an area about 30.5 by 9.2 m (100 by 30 ft). A few minutes later the animals moved closer together to occupy a surface area about 9.2 m (30 ft) in diameter. Often the spotted porpoise were observed rising vertically with only their snouts or heads clear of the water. The eastern spinners appeared more active than the spotters and appeared to remain grouped more closely during the set.

Table 10. Porpoise schools chased but not set on

Date (1978)	Position		Duration of Chase (min)	Porpoise Chased			Comments
	Lat (N)	Long (W)		Offshore Spotters	Eastern Spinners	Total	
11/20	9°45'	105°02'	15	10	190	200	20 spinners out at bow of seiner - 10 spotters out at same location - school very spread out - another group 30 spinners out by bow - chase called off.
11/26	15°23'	103°29'	38	533	-	533	100 porpoise out between bow and first 2 speedboats; 200 animals out through wake of vessel; 15 out by bow; cut out 50 animals to go after 200 porpoise; another 20 out between bow and speedboat.
11/26	15°10'	103°15'	14	1300	-	1300	50 animals between three speedboats
12/01	12°28'	103°48'	16	100[1/]	-	100	10 porpoise out off bow; 10 porpoise leave between speedboats 2 and 3; porpoise begin to scatter.
12/02	12°54'	105°52'	19	-	150[1/]	150	Spinners lost in rain squall
12/04	12°50'	108°36'	41	-	-	2000[2/]	Big school scattered out for about 2 miles; cut some out and headed for largest group; 75 spotters out between two speedboats.
TOTAL - 6 aborted chases				1934	340	4238	

[1/] Observer estimate.

[2/] Observer estimate. No breakdown by species/stock.

On an average of about three times per set, immature spotters and/or spinners would leap clear of the water. On Set 15, a very young spotted neonate was observed swimming very close to an adult, presumably its mother. The neonate still had folds on the side of its body and probably was not more than a few days old (no umbilical cord noted). The chase on this set lasted 12 minutes.

At the inception of "rolling net," a speedboat circled continuously near the stern of the vessel at the point where the net rose out of the water to the power block. The porpoise remained clear of the general area. As the net was rolled aboard, the area encompassed by the net was reduced and the porpoise positioned themselves over the deepest portion of the net. That area (bow bend) would ultimately form a portion of the backdown channel.

The porpoise and tuna were observed to position themselves near the center of the deepest portion of the net. On one occasion, divers entered the net well prior to backdown and were able to position themselves 27 to 30 meters (90 to 100 ft) beneath the porpoise school. Photos taken of the school showed a high density of animals. (A wide-angle or fisheye lens might enable divers to photograph the entire school for accurate capture estimates of small- and medium-sized schools of porpoise.)

It has long been suspected that unobserved porpoise mortality occurs in the deep areas of the seine prior to backdown. One interesting observation made by the divers was that the half-net zipper held up a wall of webbing 6.1 to 9.1 meters (20 to 30 ft) high. One eastern spinner was observed entangled in the overhanging wall of webbing and was hand released from a depth of 27.4 meters (90 ft). Other lesser folds exist in this area as well. When large numbers of tuna and porpoise are captured, the probability of animals contacting these folds is undoubtedly increased.

On Set 9, diving operations started prior to and lasted through backdown. During backdown, divers worked toward the apex, staying behind the porpoise. When the backdown channel was fully formed and about half the porpoise released, three or four "sleepers" (passive behavior) on the bottom, 15 to 30 meters from the apex, (depth 3 to 6 meters) were observed. One animal seemed greatly distressed. Its back was rigidly arched, and the porpoise lay on the net with its ventral surface resting on the fine mesh. Photos were taken of this animal and of two other sleepers. The animal with the arched back maintained the posture and did not respond to the presence of divers. The sleepers were last to leave the net, leaving awkwardly, aided by rescuers at the apex.

After the animals were released by backdown, some (less than 10 percent) swam back over the corks into the net area and were backed out a second time. This probably occurred because the porpoise were facing the seiner as they were released from the net, and once free of the net, they took off running and leaping in the general direction they were headed at release.

E. Discussion

The general area of operations during Cruise V was one that the purse-seine fleet has fished for yellowfin in association with porpoise for 10 to 20 years. When the fishery commenced in the late 1950s, the capture of porpoise (and the associated tuna) was a relatively easy task.

During this period, the seiners with speeds of 7 to 10 knots were able to approach schools of porpoise and set the net. With the passage of time, the porpoise modified their behavior so that first one, then two, three and four speedboats were required to assist the seiner in the capture of yellowfin associated with porpoise. Often, now, four and sometimes five speedboats do not ensure capture.

Porpoise very well may continue to modify their behavior in response to changing fishing practices. If so, these changes in porpoise evasive behavior may benefit both the porpoise and the fishermen. For instance, if animals during chase split up into a number of groups (one of which is carrying the associated fish or most of the fish), and if the group carrying fish can be identified, herding efforts can be concentrated on that one group. This could lead to shorter chase times, the capture of fewer porpoise, and reduced mortality. At the same time, the economics of fishing should improve through shorter chase time and increased fishing time.

VII. ANCILLARY RESEARCH

A. Background

During all the cruises aboard the Dedicated Vessel, ancillary research was included in the cruise plans to take full advantage of the opportunity to collect biological specimens that otherwise could not be collected. A -60°C freezer had been installed on the Queen Mary during the year so that certain specimens requiring quick freezing could be collected, quick frozen, and stored at a very low temperature.

B. Objectives

The specific objectives of this ancillary research were to:

1. Collect blood samples and adrenal glands from each dead porpoise for research on the effects of chase and capture (capture myopathy).

2. Collect whole brain tissue from offshore spotted and eastern spinner porpoise to histologically determine the cytoarchitecture of the cerebral cortex for the two porpoise species and compare the cerebral cortex of these species with the general mammalian pattern.

3. Collect the stomachs from yellowfin tuna (Thunnus albacares), spotted porpoise (Stenella attenuata), spinner porpoise (S. longirostris), and common dolphin (Delphinus delphis) to refine the understanding of the ecological relationships between yellowfin tuna and these marine mammal stocks.

4. Collect the standard NMFS biological and life history data from each dead animal. Additionally, osteological specimens (heads) or complete specimens were to be collected from species not normally encountered in the fishery. All available dead animals were to be retrieved from the net.

5. Maintain a marine mammal watch, the standard NMFS research set log for each set, and the Fishing Mode Record for each day at sea.

6. Launch an expendable bathythermograph (XBT) probe each day at noon and one during each set. The XBT data along with the weather data were to be radioed daily to radio weather station WWD.

C. Methods

1. Capture myopathy studies

Blood samples were collected from dead porpoise as soon after death as possible. Samples were immediately transferred into hepronized vials and centrifuged at 1,000 rpm for 30 minutes to separate out the red blood cells. Plasma samples were quick frozen at -60°C in the Solow freezer. Once frozen, they were transferred to the seiner's food freezer (-20°C) for the duration of the cruise. Organ and stomach samples were taken as soon after death as possible and quick frozen at -60°C. These samples remained at -60°C for the duration of the cruise.

2. Cerebral cortex studies

Whole brains were extracted by removing the back of the skull with a Stryker bone saw. These samples were removed whole, and injected with and stored in 10 percent formalin.

3. Comparative dietary studies

Porpoise stomachs were collected when the animals were processed for life history data, and tuna were flagged before being placed in the brine wells.

4. Life-history studies

The standard NMFS Life History data and samples were collected for all dead porpoise.

5. Standard cruise data

Standard NMFS marine mammal sighting and effort records were maintained daily throughout the cruise. Two crewmen and one scientist stood 30-minute rotating watches during all daylight hours unless prevented by unworkable sea conditions.

6. Environmental data

Expendable bathythermograph (XBT) traces were recorded on the seiner's Sipicon recorder each day at noon and during each set. The traces were coded, along with visible sea and weather conditions, and were sent to radio station WWD when possible.

D. Results

1. Capture myopathy studies

Blood samples were drawn from three porpoise, and organ tissues collected from one porpoise during the cruise. Small portions each plasma sample were test-stored in the ship's large refrigerator. These samples showed evidence of bacterial growth after 5 days. Samples stored in the ship's freezer showed no bacterial growth and are currently being analyzed by a local medical laboratory. Results of this work will be reported in a treatise on capture myopathy by Dr. Warren Stuntz, NMFS.

2. Cerebellar cortex studies

Whole brains of two eastern spinners and one offshore spotter were collected and preserved in 10 percent formalin. A separate report by Dr. R. J. Tarply (Texas A and M University) will be published.

3. Comparative dietary studies

Stomachs were collected from two offshore spotters and three eastern spinners. Forty-five yellowfin tuna were flagged. These samples are currently being analyzed and a report will be issued at a later time.

4. Biological specimens

NMFS standard biological and life history data were collected for two offshore spotters and seven eastern spinners.

5. Marine mammal information

Standard NMFS Marine Mammal Sighting and Effort Records were maintained daily throughout the cruise. During approximately 150 hours of observation, 56 marine mammal sightings were recorded. The standard NMFS set log was kept for each set and the fish mode record was kept for each day at sea.

6. Environmental data

Expendable bathythermographs (XBT) traces were collected daily at noon and during each fishing set. Local weather and sea state conditions were recorded daily and transmitted to WWD (radio weather station) when possible.

VIII. SUBMITTED BY: David B. Holts
David B. Holts, Cruise Leader

John DeBeer
John DeBeer, Program Manager

IX. APPROVED BY: R. J. Hofman
Robert J. Hofman, MMC, Member, Program Board

Frank Alverson
Frank Alverson, LMR, Member, Program Board

Will F. Perrin
William F. Perrin, NMFS, Member, Program Board

APPENDIX A. PRIMARY EQUIPMENT LIST

SCUBA diving gear
- Standard gear - mask, tanks, regulators, etc.
- Divator- full face mask
- Wet tape- Soundwave Systems
- Air compressor- Ingersol-Rand
- Underwater cameras (2)- Nikonos III and IV

Fathometer - Furuno, model FG-200, Mark 3

Inflatable raft- Avon, model S400 (served as the dive boat)

Inflatable raft- Avon, Redstart

Outboard engine- 5 Hp Johnson

Rangefinder- Leitz, model 4394

Dynamometers- Dilon: 0-910 kg, 0-3630 kg, 0-4540kg, 0-6810 kg

Spring scale- Chatillon, 0-5 kg

Movie camera (2)- Canon Scoopic, 16 mm

Centrifuge

Freezer- -60°, Solow

Brain saw- Stryker

Standard NMFS observer kit

APPENDIX B

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Fisheries Center
P.O. Box 271
La Jolla, CA 92038

October 26, 1978

TO: John DeBeer
Program Manager, Dedicated Vessel

FROM: Dave Holts
Fisheries Methods and Equipment Specialist,
SWFC Diving Officer

SUBJECT: Diving Procedures for Cruise V of the Dedicated Vessel

Goals

Southwest Fisheries Center's diving related research will center around the description and measurement of the parameters necessary to allow mathematical simulation of the purse seine operation. These studies are aimed at maximizing the porpoise release capability and overall efficiency of the fishing operation.

Objectives

SWFC divers will observe, measure and record the following specific physical characteristics of the purse seine operation:

1. Sub-surface net configuration during pursing and net rolling.
2. Mesh shape and tension profiles before and during backdown.
3. The rate of rise of the backdown channel floor.
4. Development of stern-sway and canopy formation during backdown.

Diving Conditions

The vessel will operate in the tropical open ocean waters off Mexico and Central America. All scheduled dives will be within the vessel's purse seine and during actual fishing operations. The vessel, its net skiff and speedboats will be in operation (live boating) during the diving operations. Yellowfin tuna, spotted and/or spinner porpoise and pelagic sharks will be captured in the net during most of the sets. The

closest medical facilities are in Mexico and may be up to 72 hours away by vessel.

Procedures

All diving operations conducted during Cruise V will be in strict adherence to the NOAA Diving Regulations and Safety Rules (copy attached). The dive team will consist of a Dive Master, two divers, and a dive tender.

Prior to each dive a Dive Master will be designated. The Dive Master is responsible for the safe and efficient execution of the diving operation. Prior to the dive he will describe the dive objective(s) to the Vessel Captain and Cruise Leader and give specific assignments to the individual divers.

In all diving operations the Dive Master will serve as "back-up diver" and accompany the dive tender. He will be fully equipped to enter the water and assist the primary divers should the need arise. He will also stay in contact with the Vessel Captain (via radio), maintain individual diver down times and monitor non-decompression limits.

Individual divers shall be responsible for, and ensure that:

1. He is in good physical condition, and at a high level of diving proficiency.

2. His equipment is in a safe operating condition.

3. Diving conditions are safe.

4. He does not violate the dictates of this training or the NOAA safety rules and regulation.

5. He fully understands the objective(s) of the dive and that he is capable of accomplishing them.

The dive tender will operate from a 10 h.p. powered four-man inflatable raft. He and the back-up diver will remain in the raft to provide support and assistance to the divers.

The tender will take the divers to the designated area to begin the dive. Once the divers enter the water, the tender will attach an additional two-man raft to the corkline between the third bunch and the apex of the backdown channel. This secondary platform will remain on station for use by the divers as desired.

During the dive operation the dive tender and back-up diver will be

requested to monitor the depth of the net. Using a modified depth finder they may examine and document bottom profiles while the net is being retrieved. They will, however, remain in the immediate area of the divers.

To minimize the potential dangers of diving inside a working purse seine, the following guidelines will be followed.

1. All diving operations are limited to water hauls, sets on traveling schools of tuna, and sets made for tuna in association with porpoise.

2. Diving operations are limited to daylight hours and will terminate 1 hour before sunset.

3. The "buddy system" will be used at all times. A back-up diver and dive tender will also be present.

4. Divers are not to descend beyond 130 fsw. Non-decompression limits will be determined on all dives and divers are not knowingly to exceed these limits.

5. Divers will carry a bang stick, shark dart or shark "billy" during all dives. Divers must terminate any dive in which they feel sharks pose a threat to their safety.

6. In the event of an emergency or other problem(s), one diver will release a signal buoy or surface and blow a police whistle. The Dive Master will have the fishing operation stopped while the problem is assessed.

7. Two seal control bombs will serve as a diver recall signal. They will be thrown outside the net, but in an area adjacent to where the divers are working.

8. Divers will not approach the purse cable, rings or other hazardous areas in the net.

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Appendix C - Summary of individual bottom profile transects

Bottom profile traces were recorded during Sets 1, 2, 5, 7, and 8. A Furuno fathometer was used in a four-man inflatable raft propelled by a 5-hp outboard motor. The transducer was attached to the boat's transom so that it was vertical and constantly submerged. Readings were recorded in feet. The fathometer was modified for variable chart speed, although the fastest chart speed of 5.0 cm/min was always used.

Set 1

The raw data collected during this set was not analyzed because the speed of the raft was not estimated.

Set 2

Five transects were made during Set 2 (Figure C-1). The speed of the boat was estimated at one meter per second during all transects.

Transect T-1 began one minute before rings up and T-2 crossed the mid-net zipper as the rings came up. T-1 began at about one-third net*, and the boat headed toward the seiner's ring stripper. The boat was turned about 90° to the right, about 15 m from the seiner, and began T-2 which ran to the corkline at approximately two-thirds net (buoy #4). The transects were 64 m and 67 m respectively. Maximum depth of 38.1 m were recorded on both the bow and stern side of the zipper. A depth of 35 m was recorded as the vessel crossed over the mid-net zipper.

Transect T-3 began 11 minutes after rings up, and four minutes after net rolling started. T-3 began in the bow area near the apron apex, crossed the net parallel with the seiner (about 20 m away). T-4 returned on the same track. A maximum depth of 15.3 m was recorded in bow area and the net was 8.2 m deep over the mid-net zipper. This probably does not reflect the deepest part of the net because the transects were made close to the vessel.

Transect T-5 was similar to T-3 in course and direction, but began 16 minutes after net rolling started. The transect was run parallel to the seine at a distance of 30 m. By this time the shallower mid-net zipper ridge had disappeared and a maximum depth of 17.4 m was recorded at mid-net.

Set 5

Five transects were made during Set 5 (Figure C-2). Transect speed was estimated at one m per second during all transects.

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*Starting from the bow end of the net

Transects T-1 and T-2 were each 92 m long. T-1 began at point A in the bow bend, proceeded to approximately mid-net (B), then T-2 headed toward the stern one quarter net area (C). T-1 began two minutes before rings up and T-2 ended shortly after the rings came out of the water. The maximum depth (32 m) was recorded in the stern section just after the rings came out of the water. T-2 clearly shows shallowing caused by the mid-net zipper nearing the surface. The mid-net ridge in the zipper area was confirmed by divers during all sets.

T-3 was a 79 m transect that began approximately 4 m out from the ring stripper and heading directly across the mid-net area. The transect began two minutes after rings up but well before net rolling. The resultant curve reduced from the strip chart data was compared with a theoretical curve calculated by T. N. Delmer, Science Applications, Inc. The two curves are very similar with maximum depth differing by only 1.9 m.

T-4 began just prior to net rolling and crossed the widest part of the net. T-5 was on a slightly different track which accounts for the curve differences.

Set 7

Nine transects were obtained during Set 7 (Figure C-3). The speed of the boat was estimated at 1.2 m per second during all transects. T-1 began at buoy #6, near mid-net, 8 minutes prior to rings up and the boat proceeded towards the ring stripper on the seiner. The rings and purse cable were located 30 m from the vessel at a depth of 42.7 m.

T-2 began near the seiner and ended at buoy #6. The rings and cable were located about 5 meters closer to the vessel and 1-1/2 m deeper on this transect.

T-3 began began at buoy #6 4 minutes before rings up and the boat proceeded toward the seiner's bow. A maximum depth of 32 meters was recorded. T-3 did not pass over the purse cable.

T-4 indicated maximum depths of 28.4 meters in the bow, 29 m the stern and the shallowing zipper area rising to only 16.8 m.

T-5 proceeded from the stern bend toward buoy #8. Again, the mid-net zipper area was shallower than the rest of the net, but the web had sunk 3 to 6 m in the preceding minutes.

T-6 began near the seiner's ring stripper just after net roll while T-7 proceeded from the stern bend toward buoy #8. Maximum depths of 29 m were recorded in the stern bend. These shallowed to about 12 m over the zipper area. Net roll had started 1 to 2 minutes prior to these transects and the net was still very deep in the stern area.

Transects T-8 and T-9 produced very similar traces. T-8 began 6 minutes after net rolling started and T-9 started two minutes later. Both indicate shallowing in the stern bend as the net was rolled aboard the vessel. Also, both indicate depths of 28 m below the bunches in the bow bend. T-8 crossed over the zipper about 33 m from the vessel while T-9 crossed at 60 m.

Set 8

Five transects were obtained during Set 8 (Figure C-4). Boat speed was estimated at 1.25 m per second for transects 1-3 which passed over the leadline. The deepest point (47.3 m) was recorded during T-2 almost 14 minutes before rings up. Two minutes later the leadline was recorded at 27.5 m (T-3) giving a rising rate of about 10 m per minute.

Transect T-4 began (boat speed was 0.58 m/sec) in the stern bend three minutes before rings up and ran into the bow bend, staying about 20 m away from the vessel. The maximum depth of 47.3 m was recorded in the stern. The raft crossed the zipper (32.0 m) roughly 1-1/2 minutes before rings up. This transect ended forward of the vessel's bow as the rings came up and the first bow bunch was being pulled.

Transect T-5 proceeded from the bow bend (at 0.70 m/sec) to the center of the net opposite the ring stripper. It started one minute after net roll and indicated the maximum depth of 27.5 just on the bowside of the zipper. Surprisingly shallow depths (16-20 m) were recorded in the bow bend.

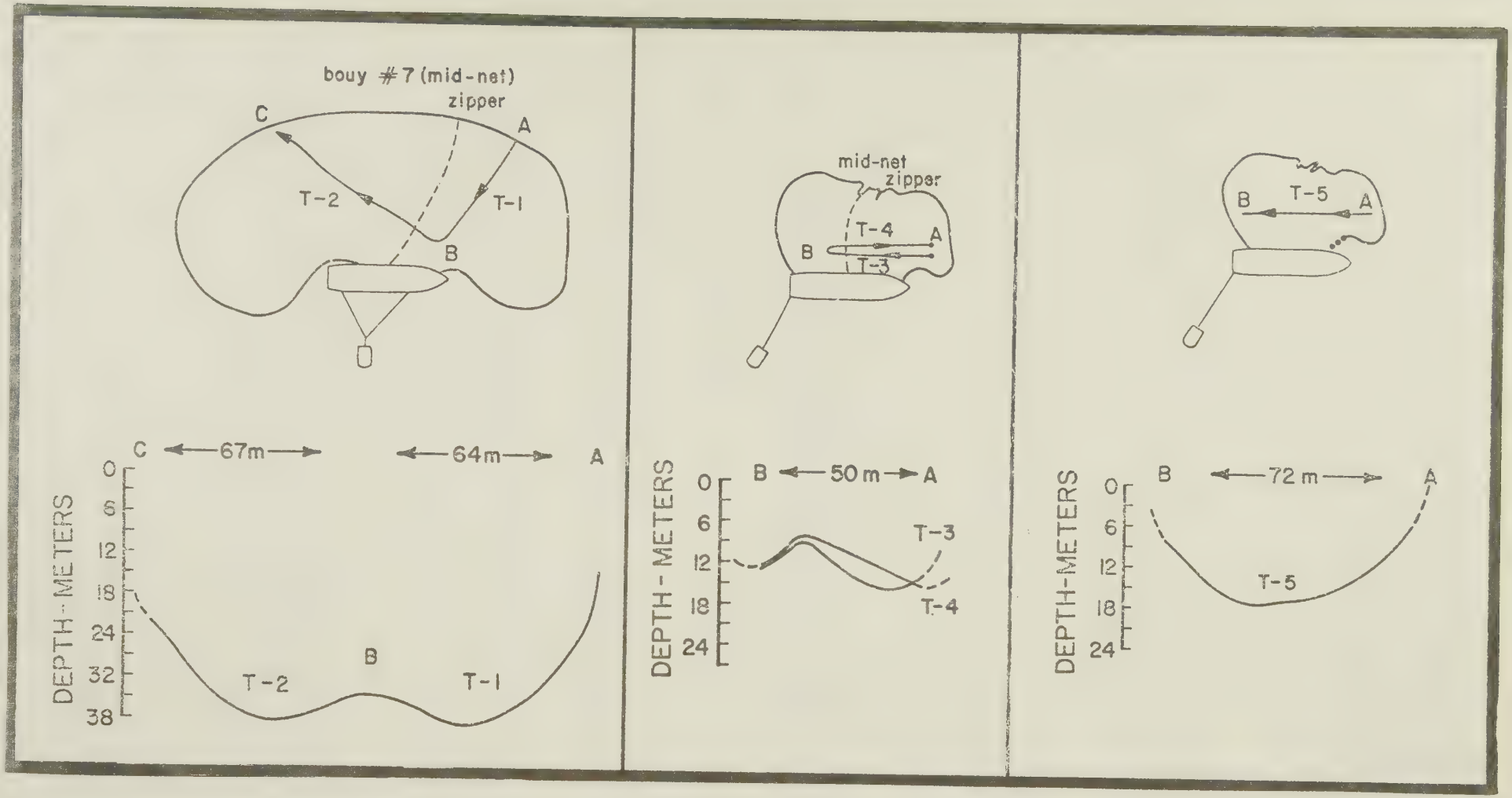

Figure C-1, Set 2, Transects 1-5

T-1 - Started one minute before rings up
T-2 - Crossed zipper so rings came out of water
T-3 - Started 4 minutes after net rolling began and ran parallel to the seiner at a distance of ∿20 meters
T-4 - Returned on same track as T-3
T-5 - Began 16 minutes after net rolling started, ran parallel to the seiner at a distance of ∿30 meters

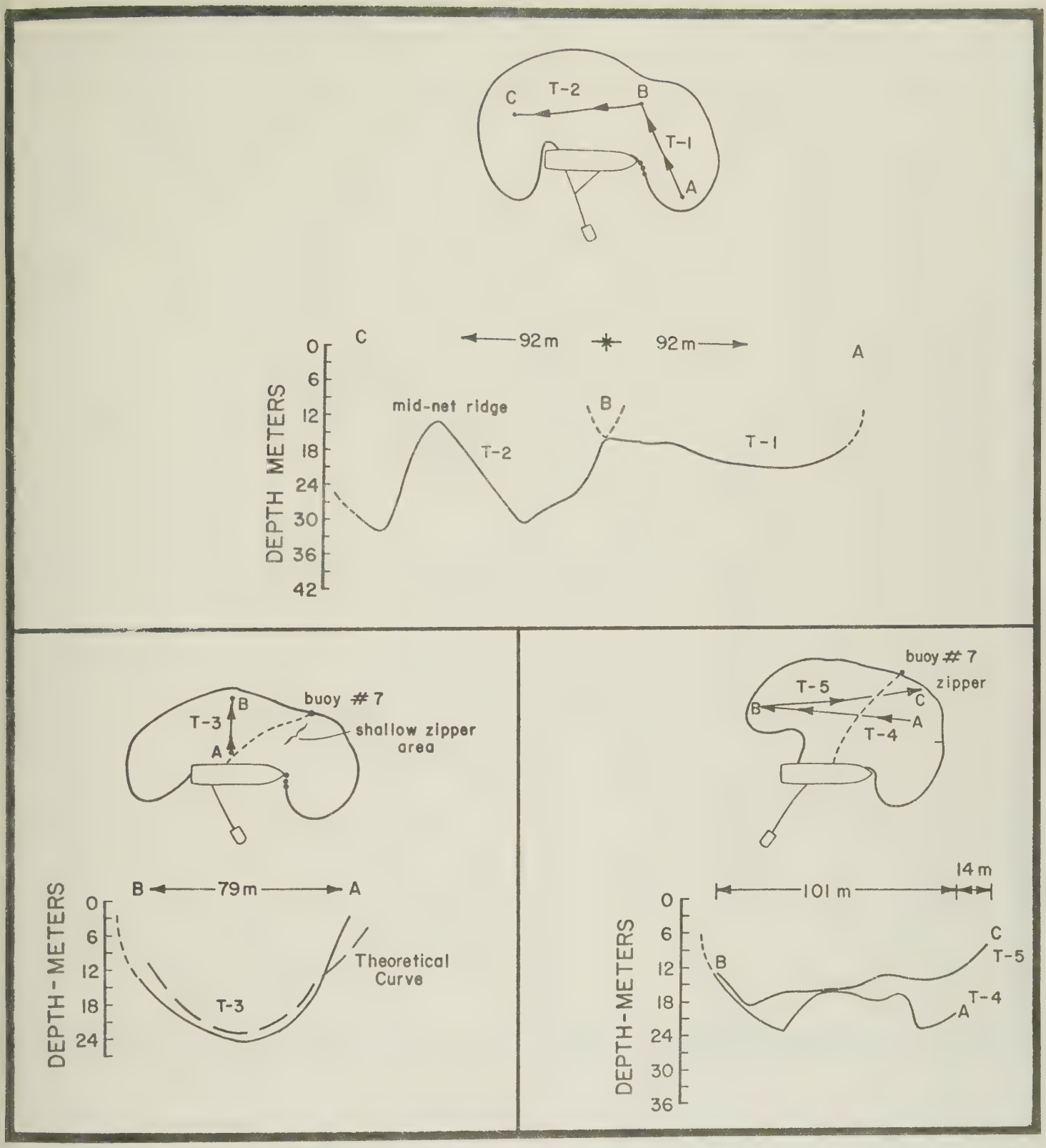

Figure C-2, Set 5, Transects 1-5

T-1 - Began 2 minutes before the rings came up
T-2 - Ended shortly after rings up
T-3 - Began 2 minutes after rings up
T-4 - Began just before net rolling started
T-5 - Began at the start of net roll

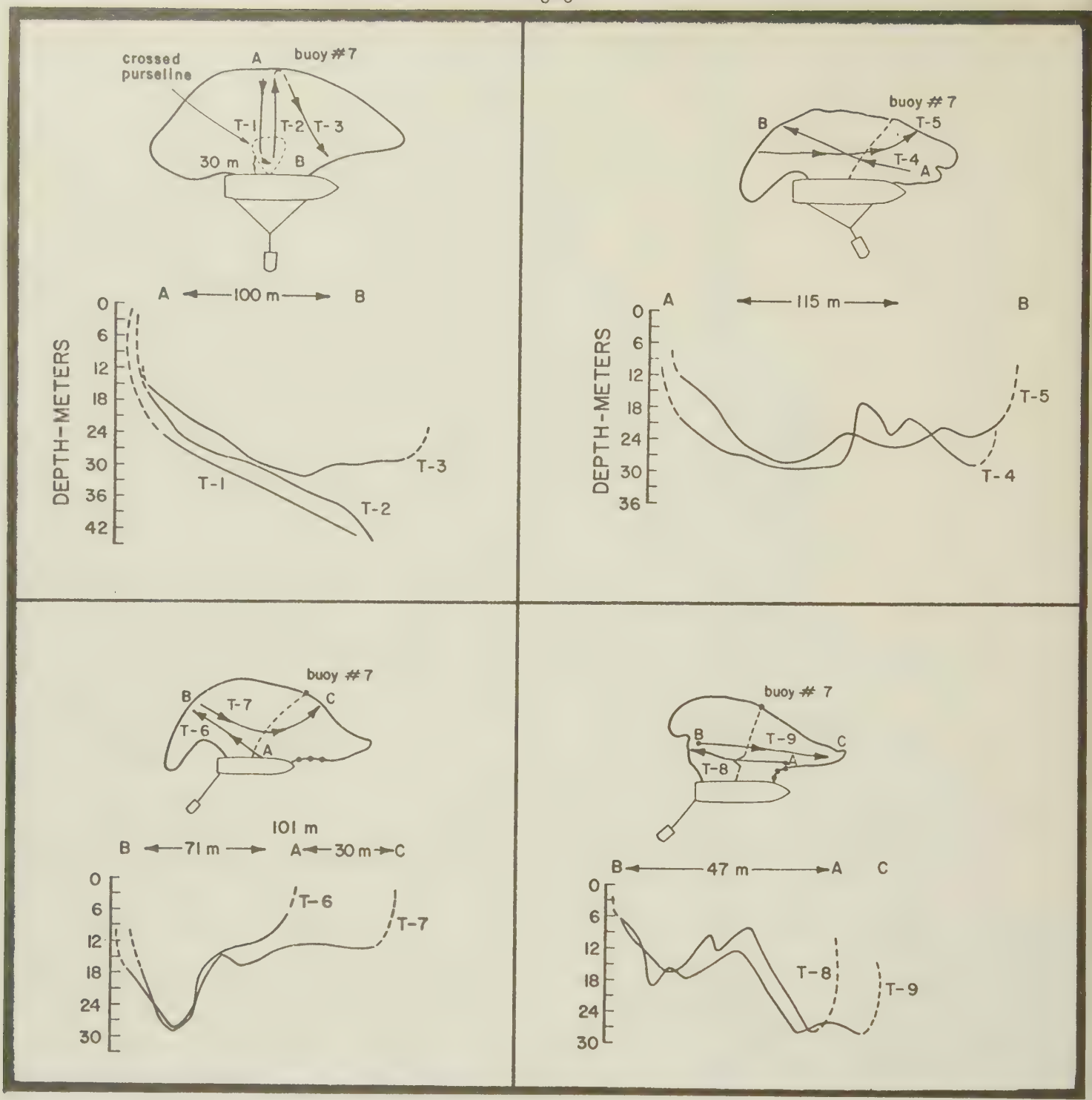

Figure C-3, Set 7, Transects 1-9

T-1 - Began at buoy #6, 8 minutes prior to rings up and passed over the leadline (B) 30 m from the seiner
T-2 - Ran back towards buoy #6 and located the leadline 25 m from the seiner
T-3 - Began at buoy #6, 4 minutes before rings up but did not cross over the leadline
T-4 - Began 1 minute before rings up in the bow area of the net
T-5 - Began in the stern bend area of the net 1 minute after the rings came up
T-6 - Began at the ring stripper just after net roll started
T-7 - Started 2 minutes after net roll
T-8 - Started 6 minutes after net roll
T-9 - Started 8 minutes after net roll

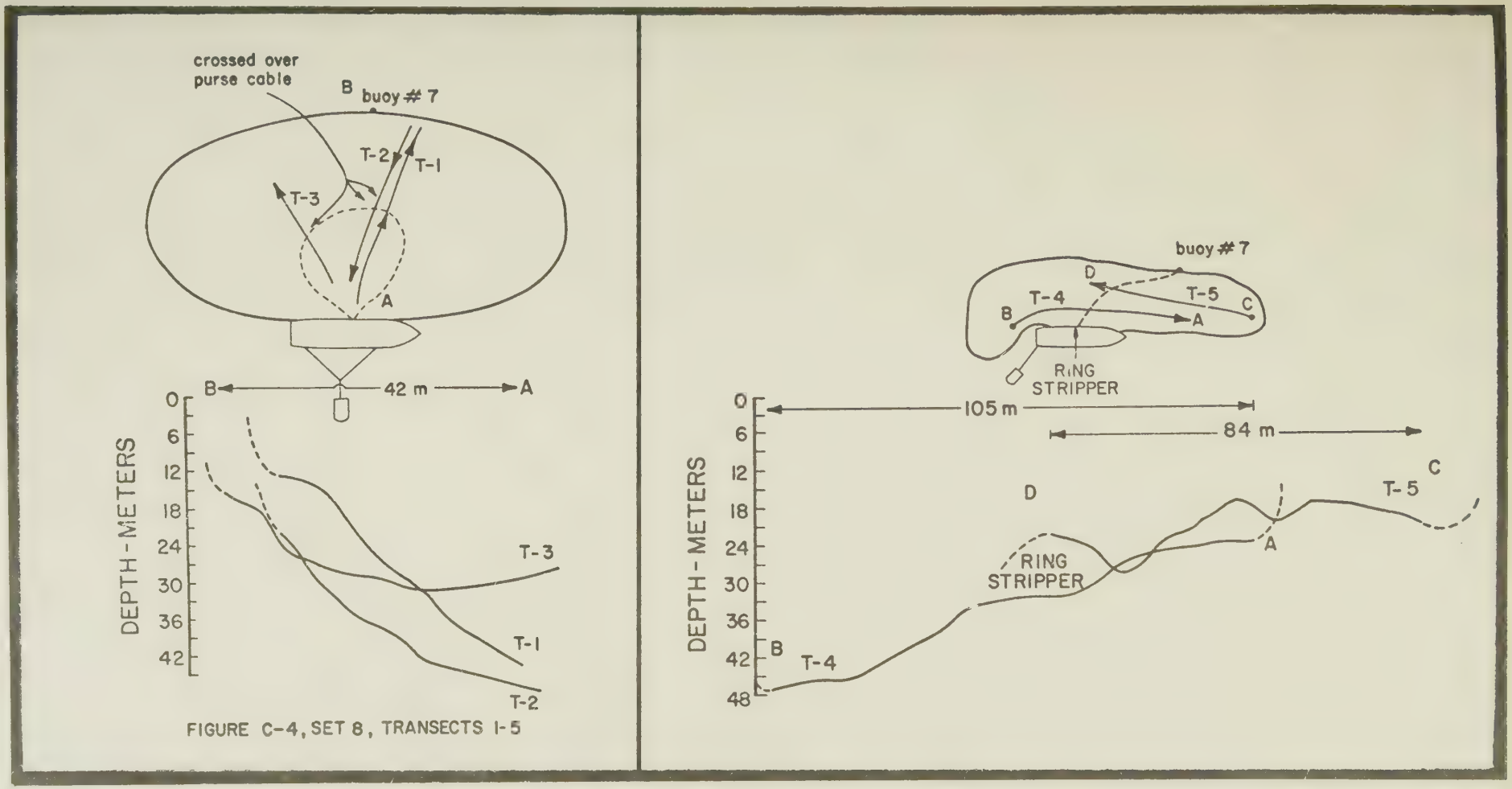

FIGURE C-4, SET 8, TRANSECTS 1-5

Figure C-4, Set 8, Transects 1-5

T-1 - Began at the ring stripper 16 minutes before rings up, when the net was about half pursed, and ran towards buoy #8

T-2 - Returned on the same track and crossed the purse line 14 minutes before rings up. The depth of the purse line was 47.3 m

T-3 - Began at the ring stripper and ran towards buoy #4. The purse line was located 12 minutes Before rings up at a depth of 27.5 m

T-4 - Began in the stern bend of the net 3 minutes before rings up, and ran parallel to the vessel at 20 m, towards the bow bend

T-5 - Began in the bow bend 1 minute after net roll started